UNIVERSITY OF CALIFORNIA SAN DIEGO

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Precision Health Research Biobanking with Professional Athletes in the US: A qualitative study using Dissemination and Implementation Science

A Dissertation submitted in partial satisfaction of the requirements for the degree Doctor of Philosophy in a Joint Doctoral Program

in

Public Health (Health Behavior)

by

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The Dissertation of Julie Ann Cakici is approved, and it is acceptable in quality and form for publication on microfilm and electronically.

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2023

DEDICATION

To my loving husband, Oguz Cakici. Your love and support have been the keys to my success. I truly cannot thank you enough.

EPIGRAPH

“The product is a human body, well, where's the ethical line in there?”

~ Former NFL Player

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LIST OF ABBREVIATIONS

Alliance	Wu Tsai Human Performance Alliance
CAB	Community Advisory Board
DIS	Dissemination and Implementation Science
ELSI	Ethical, legal, and social implications
GDPR	General Data Protection Regulation
GWAS	Genome-Wide Association Studies
HPR	Human Performance Research
KII	Key Informant Interviews
LMIC	Low- and middle-income countries
NIL	Name, image, likeness
OHRP	Office for Human Research Protections
PRISM	Practical, Robust, Implementation and Sustainability Model
RE-AIM	Reach, Effectiveness, Adoption, Implementation, and Maintenance
UCSD	University of California San Diego
UNESCO	United Nations Educational, Scientific and Cultural Organization
US	United States of America

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ABSTRACT OF THE DISSERTATION

Precision Health Research Biobanking with Professional Athletes in the US: A qualitative study using Dissemination and Implementation Science

by

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Doctor of Philosophy in Public Health (Health Behavior)

University of California San Diego, 2023

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Background: Moving from studying diseases to states of optimal health brings new logistical, ethical, legal, and social implications for Precision Health research. The Wu Tsai Human Performance Alliance seeks to study elite performers in precise detail to understand both human performance and translate these findings to the public on a global scale. To achieve their

goals, the Alliance is implementing a biobank, which collects, stores, and shares biological samples and health information for future, unspecified research. To inform the design, conduct, and implementation of their Precision Health research and biobank, this study sought to explore the contextual factors of professional sports in the US that may impact successful research implementation. Potential adaptations to improve the acceptability and, by extension, the generalizability of this research were also identified.

Methods: Dissemination and Implementation Science (DIS) was adapted from implementing evidence-based interventions for the implementation of Precision Health research interventions. This exploratory study conducted one-hour, semi-structured, key informant interviews of professional athletes (n= 20) and their non-athlete stakeholders (n= 22) using an adapted version of the Practical, Robust, Implementation and Sustainability Model (PRISM). A hybrid qualitative method was used to simultaneously apply deductive structured codes from PRISM and inductive codes based on grounded theory.

Results: Overall, participants reported interest in the Alliance's research, but willingness to participate or to encourage athletes to participate was usually conditional. Major themes were vulnerabilities (athletes' characteristics and risks for discrimination), the impact of the research (potential for negative impacts on sports industry and widening health disparities), desires for direct benefit (e.g., individual results or profit-sharing), and decision-making (desires to control usage of samples and data). Several adaptations to traditional research practices, such as data embargoes and dynamic consent, were identified as likely to increase the perceived acceptability of the research and by examining DIS outcomes were theorized to improve the generalizability of the research.

Discussion: This study provided evidence for the utility of supplementing ethical, legal, and social implications (ELSI) research with DIS methods for planning early-stage research intervention implementation. This study described the logistical, ethical, legal, and social implications of human performance research (HPR) and biobanking for aspiring and professional athletes, while identifying key decision points and potential impacts on implementation outcomes. This study allows researchers to make data-driven decisions to adapt traditional research practices to make the research more acceptable and accessible to future participants with the ultimate goal improve the study's ability to recruit a representative sample.

INTRODUCTION

Precision Health is defined by the CDC as a broad effort to understand individual health that takes into account genomic and other omics data, such as metabolomics and epigenetics, along with one's behaviors and environmental exposures.[1] Although Precision Health includes Precision Medicine, this study refers to Precision Health research that seeks to understand extreme states of health in order to understand how exceptional health functions in order to improve health functioning for all. Precision sports-medicine is a type of Precision Health research that is derived from HPR of elite athletes that promises numerous potential benefits for both elite and amateur athletes as well as the general public, such as decreased healing time and personalized training to optimize human performance.[2,3] In order to achieve statistical power for and generalizability of these Precision Health outcomes, researchers much enroll large, representative numbers of elite performers, which often requires participation from multiple research sites to improve the sample's diversity.[4-6] To facilitate amassing statistical power, Precision Health research utilizes biobanks to collect, store, and share biological samples and health information amongst researchers.[2,7]

However, Precision Health research and biobanking raise many ethical considerations, conflicts of interest between stakeholder groups, and risks to the individual participants.[2,7,8] Although various potential participant cohorts (e.g., military personnel and child athletes.) are expected to have different barriers and facilitators to participation in Precision Health research biobanking, professional athletes are believed to have the most complex risk-benefit ratio related to research participation among elite performers.[9-12] Risks for this group include; legal (e.g., discrimination and contract negotiations.), the potential to re-identify an individual from anonymized research data due in part to the large amount of publicly available information on

this group and due to their celebrity status, and risk for research-participation coercion due to the power dynamics between teams, players, players associations, and agents.[2,7,9,13-17] There is some data about elite athletes' opinions on clinical genetic testing for sports performance and injury prevention, the two existing survey studies include a very small number of US athletes, most of whom are not likely athletes who are part of major US sports.[3,18] Beyond these studies, little is known about the attitudes and beliefs of professional athletes regarding human performance and biobanking research in the US.

Despite a lack of information about professional athletes' perceptions of Precision Health research and biobanking, there is extensive research about biobanking and Precision Medicine research that shows variability in acceptance of broad consent and types of secondary research use, which are key components of Precision Health research biobanking.[19-22] Therefore, it is reasonable to expect adaptations to traditional biobanking policies (e.g., broad consent) and procedures (e.g., researchers governing samples) will be necessary to address the context, risks, and benefits for professional athletes, or athletes who seek to obtain professional status, in order to make this research acceptable to this cohort and their related stakeholders.

The development of these adaptations will require an iterative approach that includes early and ongoing engagement of diverse stakeholders. By protecting those at the greatest risk of harm (i.e., professional athletes), these adaptations are also anticipated to confer benefits other cohorts (e.g., Olympic athletes and elite military). However, Precision Health research lacks rigorous methods for planning, designing, implementing research interventions and assessing implementation outcomes, such as acceptability, appropriateness, and adoption by stakeholder groups who are not themselves participants.[23-27] Therefore, this study employed Dissemination and Implementation (DIS) Science methods to evaluate the effect various contextual factors may

have on Precision Health research implementation outcomes, such as ability to reach the target representative sample of the population.

By using DIS frameworks, the unique concepts, contexts, barriers, and facilitators that exist in each distinct cohort (e.g., professional athletes, military personnel, and child athletes) can be compared consistently and over time. Similarly, adaptations to traditional biobanking policies and procedures can be systematically documented and compared between cohorts, which can also inform the development of other biobanks.[28] However, DIS has traditionally used to evaluate the implementation of evidence-based best practices in various settings (e.g., clinical, community, and country-level), and although a research biobank is a gold-standard for Precision Health research, it is not an evidence-based best practice.[29] Therefore, the first aim of this study was to explore how DIS methods can enhance the planning, design, and implementation of Precision Health research interventions. This study describes the theoretical adaptations required to expand the application of DIS methods to research implementation.

Following the theoretical adaptation of DIS for implementation of research interventions, this study adapted and operationalized DIS methods using the Practical, Robust, Implementation and Sustainability Model (PRISM), which adds contextual components to the implementation outcomes from the RE-AIM (reach, effectiveness, adoption, implementation, maintenance) framework, to apply to HPR and biobanking for the Wu Tsai Human Performance Research Alliance.[5,30-32] Through the integration of PRISM, this study demonstrates the utility of DIS methods during the planning phase of Precision Health research biobank implementation.[31,32] Specifically, this study conducted key informant interviews (KII) with both professional athlete and non-athlete stakeholders (e.g., agents, coaches, team owners, and researchers) to understand the contextual factors affecting the acceptability and potential to recruit a representative sample

of aspiring and professional athletes for Precision Health research biobanking, the appropriateness and subsequent adoption for the non-athlete stakeholders/organizations, and the appropriateness and feasibility from the perspective of the research teams. This study also explored potential conflicts of interest and the power dynamics between stakeholder groups to inform how future community engagement efforts should be conducted to ensure that athletes' voices are equitably represented. This study used a hybrid analysis method that allows for both structured (deductive) and unstructured (inductive/thematic) qualitative data analysis.[33] This study assessed the contextual domains and implementation outcomes from PRISM for a structured analysis of the qualitative data.[31,32] This study also employed traditional grounded theory data analysis to uncover new themes from the qualitative data.[34-36]

Following the analysis of these data, barriers and facilitators to HPR and biobanking were identified. Recommendations based on the literature and the interview data were made and discussed in both the Implementation Findings and White Paper Recommendations.

Specific Aim 1: Theory Adaptation- Using Jaakkola's methods for theory adaptation for conceptual papers, this aim explores how DIS methods can enhance the exploratory and design phases of implementation of Precision Health research interventions.[37] This aim discusses and justifies the appropriateness and utility of using DIS methods for implementing Precision Health research interventions.

Specific Aim 2: Theory Application for Qualitative Exploration

2a. Theory Application- Operationalization of PRISM to assess contextual factors, including attitudes and beliefs, that are likely to impact the successful implementation of HPR and biobanking amongst professional, competitive

athletes in the US to inform future adaptations, policies, and engagement activities.

2b. **Qualitative Exploration-** Explore attitudes, beliefs, and intricacies of stakeholder relationships in professional sports' contexts through KII to inform future stakeholder engagement and identify critical considerations and potential adaptations and policies for implementing a HPR and a biobank in this context. Interviews focused on understanding potential impact of this research, barriers and facilitators to conducting this research, and exploring which stakeholder groups should be involved in informing the design of this research.

Impact: This study expands the application of DIS methods and best practices to include implementation of research interventions, particularly complex and costly Precision Health research and biobanks. This study also provides a detailed description of how DIS methods can be operationalized in an iterative stakeholder engagement process and demonstrates the application of DIS methods to community engaged research implementation through the KII process. By incorporating these rigorous DIS methods traditionally used in clinical research, this study shows how DIS can be used to inform and evaluate future engagement efforts in other cohorts and other biobanks to evaluate the impact adaptations have on implementation outcomes.[29]

This study also addresses a critical gap in the literature by exploring the attitudes and beliefs of professional athletes' and the non-athlete stakeholders who work closely with these athletes regarding precision health research, biobanking, and how to engage. The data collected by this study provides an assessment of the contextual factors within the sports industry that may impact successful Precision Health research intervention implementation and describes the

perceptions of athletes and non-athlete stakeholders to allow researchers to make data-driven decisions on how Precision Health research should be designed and conducted with this group. Key barriers to successful implementation included the high risk for loss of confidentiality and potential for discrimination in this population, the need for research to return direct benefit to participants, and the importance of engaging and empowering athletes in the decision-making process. In addition to addressing this gap in the literature, this study incorporates the existing Precision Medicine literature to provide recommendations for policies, research design and practice changes, and engagement strategies to improve the acceptability of this research. This study hypothesizes that improving the acceptability of Precision Health research will lead to more diverse recruitment, improved generalizability of future research, and scalability to population-health levels.

CHAPTER 1: Background and Significance

1.1 Health Impact

In order to facilitate future Precision Health research, the purpose of this study was to understand the barriers and facilitators of Precision Health research aimed at understanding and improving human performance. This research was funded and conducted in collaboration with the Wu Tsai Human Performance Alliance (the Alliance) and their biobank research team at the University of California San Diego.[5,30] The Alliance's stated mission is to better understand biological factors associated with elite performance in order to ultimately help "all people to achieve optimal health and well-being."[5] In order to achieve this aim, the Alliance proposes moonshots that include creating a digital twin to better understand movement and guide trainings and treatment, regenerative medicine projects to improve healing time and recovery, build a molecular athlete in order to understand tissue function at the molecular level, and a project designed to bring together all of these other projects to assess overall physical performance.[5] Beyond these moonshots, the Alliance funds additional work through their Innovation Hub, such as the Female Athlete Program and various performance and sports sciences laboratories.[5] The Alliance has also partnered with UNESCO to promote human performance and HPR worldwide, stating one goal is to ensure that the data and samples collected through the Alliance are available to the world.[5] To facilitate the internal and future global research, the Alliance is developing a biobank, which will collect, store, and share health information and biological samples (e.g., blood and/or tissue samples) for future research.[5,30]

The primary tissue of interest is muscle tissue within the Alliance, and there are countless future impacts this research may have. As of 2022, the World Health Organization (WHO) estimated that musculoskeletal conditions are estimated to affect 1.7 billion people worldwide

and are frequently associated with disability or loss of function.[38] A subset of musculoskeletal injuries are job-related repetitive motion or strain injuries. The Centers for Disease Control and Prevention's (CDC) National Institute for Occupational Safety and Health estimated in 2015 that these injuries costs American companies $20 billion per year in direct costs and an additional $100 billion on losses from indirect expenses, such as turnover and decreased productivity, and these figures fail to capture costs and impact on the individual laborer.[39] Mastery of repetitive motions is often a major component of success in sports, but this mastery can result in overuse injuries in 30-40% of individual and teams sport athletes.[40]

Improvements in the understanding, detection, and treatment of these disorders are likely to not only alleviate pain, but improve quality of life, ability to conduct daily activities, and have economic benefits, with impact being very significant if realized at scale globally. However, biomedical research and Precision Medicine research face many challenges to obtaining population-level generalizability; common barriers include scientific preference for homogenous cohorts, lack of access or opportunity to participate in research, distrust in medicine and/or science, and lack of perceived benefits from research participation by prospective participants.[41-57] At the same time, there are logistical challenges, such as the need for very large cohorts, limited resources for on-going community engagement efforts, and limited resources available for returning individual-level results.[4,6,7,58-62] Community engagement and shared-decision making have been identified as a critical means to improving trust, diversity, and perceived benefits.[51,57,59-61,63-78] Scaling Precision Health research to the population-level will require addressing the ELSI as well as the logistical challenges of the research in order to be successful.

1.2 Precision Health Research

Precision Health research has been largely focused on an individual-level and focused on disease states, typically referred to as Precision Medicine.[1] As Precision Health evolves into states of extreme health and expands into the population-level, logistical, ethical, legal, and social implications new and old will determine its success or failure.[79-85] Some of the current problems facing Precision Health's transition to the population-level are the lack of diversity amongst existing research participants, distrust in researchers, lack of meaningful benefits for marginalized communities, and lack of equitable scalability of interventions due to access and health disparities.[79,84,85] General consensus in the social sciences advises that researchers need to be more engaged in their communities to improve research acceptability and accessibility.[45,51,59,65,67,68,86]

As learned from the Precision Medicine literature, Precision Health research needs to take into account the context into which the research will be operating. To date, community engagement has been determined to be the best method for assessing both logistical issues and the contextual factors related to Precision Health research interventions, including many of the ELSI of Precision Medicine.[51,59-61,65-69,87] Despite a relatively long history of assessing knowledge, attitudes, and beliefs of community members, Precision Health research has limited examples of studies that incorporate the feedback into study designs and practices. The most common adaptation has been the introduction of returning research results to participants, and the national *All of Us* research initiative has been the most notable example due to its scale, aiming to enroll over one million participants.[88-90] Barriers to integrating patient and community feedback in Precision Health research are often due to engagement efforts that occur after funding is obtained and research designs are immutable.[51] However, Lee et al. (2019) argue that

engagement activities need to occur much earlier in the research implementation process to allow for the research design and practices to be adapted to match the community's values.[51] Another often overlooked factor in adapting research designs and practices are the logistical issues researchers themselves face. Therefore, Precision Health research needs to expand its current engagement to a systems-level assessment that can incorporate a multi-level analysis, quantitative and qualitative assessments of both contextual factors and markers for successful research implementation.

Sports Medicine and Exercise Science are well-established fields of study, but with the rise of Precision Health related omics technologies, new fields of study such as Sports Genomics and HPR are evolving and expanding the breadth and depth of research on elite physical performance. [2,7,91-95] With this evolution comes new opportunities, such as regenerative medicine, as well as new risks and ethical concerns, such as gene-doping.[2,8,13,96-98] Researchers conducting Sports Genomics research with elite athletes include consent, return of results, reproducibility, and confidentiality as major concerns for including elite athletes in research and scaling-up.[2,99]

As previously mentioned, Precision Health research, which includes Precision Medicine research, needs to have large sample sizes, detailed and standardized phenotyping, and be reproducible.[2,4,6,7,92] To facilitate the scale required for this research, biobanks are the gold-standard of Precision Health research. Biobanks allow researchers to collect, store, and share biological samples (e.g., blood and tissue) and health information for future, unspecified research.[100,101] Biobanks are not new, however, and the ELSI of biobanking has been well described in both the Precision Medicine and public health domains, and the literature includes issues of consent, return of results, confidentiality, and governance.[2,60,64,76,77,99,102-112] Similarly,

there are numerous biobanks worldwide that target elite athletes and that describe the unique ethical and logistical issues related to biobanking for genetic discovery.[2,7,113] In addition to the omics-related scientific issues of scalability, data quality, and reproducibility, ELSI issues, such as commercialization and discrimination, have been also identified in the literature specific to elite athletes.[2,7,13,92,114]

More detailed discussion on the literature relevant to Precision Health is included in the Discussion Section and Background subsections of the White Paper Recommendations Section.

1.3 Professional Athletes

Although the various potential participant cohorts (e.g., military personnel Olympians, and child athletes) have different barriers and facilitators to participation, professional athletes are believed to have the most complex risk-benefit ratio.[9-12] For example, precision sports medicine could greatly improve athletes' performance.[2] However, professional athletes' employment is based solely on their ability to perform physically under intense conditions, and legal protections afforded by the Genetic Information Nondiscrimination Act (GINA) are complicated and have not been tested in court for this group.[13,115] More examples of potential risks for this group include: legal (e.g., employment discrimination and contract negotiations), reidentification due to the large amount of publicly available data about them and their celebrity status, and risk for participation coercion due to the power dynamics between teams, players, players associations, and agents.[2,7,9,13-17]

Furthermore, professional athletes in the US have been historically difficult to recruit into research studies and thus little is known about their attitudes and beliefs regarding human performance and biobanking research. Despite the depth of discussion amongst researchers about the logistical issues and ELSI of Precision Health research with elite athletes, few studies include

the perspectives of athletes and other non-athlete stakeholders, such as family members, training and medical staff, agents, and union representatives. Studies that do include the perspectives of professional athletes have historically focused on genetic testing and screening by teams.[3,18,116,117] Three survey studies targeting professional athletes' experiences with, attitudes, and opinions of genetic testing have been conducted in Europe, with one including a small number of professional athletes from the US.[3,18,117] These studies explored athletes' and support staff's experiences with team-driven genetic testing as well as personal experiences with direct-to-consumer testing.[3,18,117]

Student athletes are frequently targeted for research studies, including performance research, surveys, longitudinal studies, and qualitative studies. Researchers have evaluated the impact of sickle-cell screening for NCAA athletes, including the perspectives of students, coaches, and administrators.[12,118,119] Genetic screening for increased risk of poor recovery from traumatic brain injuries has also been explored amongst student athletes.[120] This study assessed interest in screening along with interest in secondary findings (returning results of known, pathogenic, genetic findings related to various diseases prior to symptom onset) and willingness of student athletes to share their results with other non-athlete stakeholders.[120] Another study sought to explore genetic associations with personality and mental fortitude amongst adolescent soccer players in the United Kingdom.[116] Concerns raised by athletes included stigmatization, exclusion from training and competition, access to information, and the return of benefit. [3,12,18,116-120] However, as shown, little is known about professional athletes' perspectives about Precision Health research.

More detailed discussion on the relevant literature to Professional Athletes is included in the Discussion Section and Background subsections of the White Paper Recommendations Section.

1.4 Dissemination and Implementation Science

As the name implies, DIS is focused on implementing research into practice (either clinical, community, or both), which requires testing the research's effectiveness and a pragmatic, multi-level dissemination effort.[29] There are four phases of the implementation process: exploratory, design, implementation, and sustainment.[121] Similarly DIS emphasizes understanding the context in which an intervention will be implemented prior to attempting implementation, ideally in the study's exploratory and design phases.[31,32] Context is considered at multiple levels and includes organizational, participant, and intervention characteristics as well as external factors such as laws and societal influences.[31] Once the context has been evaluated, one can assess how the various characteristics of the multilevel context affect the implementation process and research outcomes.[31,32,122] DIS also provides rigorous methods to evaluate and document adaptations to the intervention and implementation strategies, which includes community engagement, in order to ultimately improve outcomes.[23,28,123]

DIS includes models and frameworks for conducting qualitative and quantitative multi-level, and often iterative assessments that engage end-users (e.g., patients or community members) as well as stakeholders within the system throughout all phases of the implementation process.[29] Implementation strategies include many touch-points with recipients and stakeholders, and there are numerous methods to capture data iteratively throughout the entire implementation process.[124-129] Furthermore, implementation outcomes are more holistic than typical efficacy outcomes of research, and one of the most popular models equally prioritizes and assesses

recruitment, stakeholder adoption, research effectiveness, implementation, and sustainability of the intervention.[32,130] Similarly, there are more conceptual implementation outcomes such as acceptability, appropriateness, and feasibility, which all have validated measures.[23,131] DIS can also be applied to focus on equity and reducing health disparities.[132-135] Lastly, DIS provides methods to track adaptations made to the intervention throughout the implementation process and measure their impact on implementation outcomes.[28,136]

Traditionally, DIS was designed to introduce research that has previously been determined to be efficacious.[29] Precision Health research increasingly falls into a grey-zone between research and clinical intervention.[137] As DIS is intended to bring research into practice, it is no surprise that DIS is already being used for implementation of genomic testing in Precision Medicine.[138-143] Similarly, more recent recommendations to integrate DIS earlier into translational research for Precision Medicine describe how DIS could facilitate discovery, but integration frequently occurs only at the clinical stages and still fails to translate into public health impact.[144-146] One group of researchers has already begun using DIS for biomarker research in the T0 phase and mapping Precision Medicine factors along the translational research continuum to DIS strategies and outcomes.[147] Nonetheless, DIS has rarely been applied to purely research interventions, but there exists opportunity to expand its scope to improve the translational continuum and ultimately promote population-level implementation.

1.4 Significance

Sports-medicine derived from precision HPR of elite athletes carries numerous potential benefits to both elite and amateur athletes, as well as the general public.[2,3] However, it also brings many ethical considerations, conflicts of interest between stakeholder groups, and risks to the individual participants.[2,7,8] As Precision Health research expands to include different cohorts

and integrates more mulitomics technologies (e.g., proteomics, phenomics, and/or metabolomics), the original assessments of the risks and benefits of biobanking research are proving to be outdated as the lines between research and clinical care blur, reidentification risks evolve, and privacy concerns seep into the headlines.[137,148-150] Although still allowable under the Revised Common Rule, treating biological specimens and data as non-human subjects research is one of the driving factors for the lack of diversity in biobank recruitment, which threatens the generalizability of Precision Health research.[137,151-154] To redress the wrongs of the past and to respect the wishes of more diverse communities being recruited, biomedical researchers have begun to value and utilize community engagement activities.[49,63,68,69,71,74,78,154,155] More recently, engagement activities have shifted to go beyond educational efforts and be more inclusive of the community in the research decision-making process.[78] However, these engagement activities typically report conclusions and propose recommendations for future research, but the discussions often lack reporting of robust data related to multifaceted outcomes, such as costs related to adaptations made from the engagement or improvements in community-perceived acceptability of the adapted research; this situation leaves future research teams to choose engagement activities and make adaptations without empirical data.[24-27]

The new Wu Tsai Human Performance Alliance seeks to understand how optimal performance is achieved in elite performers to improve human performance for everyone.[5] Research aims targeting the global population require recruitment of a very diverse cohort of elite performers at a large enough scale to provide statistical power for multiomics research and collaboration amongst researchers across multiple sites.[4-6] To facilitate the aggregation of large numbers of samples and data across sites, a Precision Health research biobank is being created for this HPRendeavor.[30] However, in order to mitigate known and new risks, an iterative

engagement process with potential participants and their stakeholders is necessary, and adaptations of traditional biobank policies (e.g., offering only broad consent) and procedures (e.g., simple de-identification via research ID) will likely be required to make the research more acceptable to elite performers.

To date, there are only two studies that looked at elite athletes' opinions on genetic testing for sports performance and injury prevention. These studies included a very small number of US athletes, who were unlikely to represent opinions from major US sports.[3,18] Therefore, it is critical for researchers to understand the multilevel contextual factors that influence attitudes and beliefs towards Precision Health research biobanking amongst professional athletes. By exploring these contextual factors from both professional athletes and non-athlete stakeholders, this study provides detailed descriptions of the anticipated impact of this research along with the barriers and facilitators to professional athletes' participation. This study sought to integrate assessments of contextual factors and implementation outcomes into the early stages of engagement and research design by adapting an existing methodology, DIS, to utilize structured data analysis to inform the implementation of a Precision Health research biobank in collaboration with the Alliance. By adapting DIS methods, this study demonstrates how data can be captured and analyzed to anticipate the potential impact that unique contexts can have on research outcomes.

Therefore, this study begins by adapting DIS for application to Precision Health research interventions. By integrating DIS into the exploratory and design phases of research, researchers will have tools to evaluate the contextual factors using implementation strategies, including multi-level stakeholder engagement.[29,133,135,144,147,156,157] This integration of DIS also provides tools to assess the impact adaptations had on their research designs and practices, as well as on

implementation outcomes. to assess the impact adaptations made to their research designs and practices have on implementation outcomes.[28,136] DIS allows researchers to apply a common language and qualitatively and quantitatively assess implementation outcomes that go beyond research efficacy from T0 through T4.[144,158] This study seeks to build on this foundational work and the work of Chambers et al. 2016 who expanded DIS to Learning Healthcare Systems to explore how DIS can be adapted and better conceptualized across these early phase research studies.[144,147] By conceptualizing all stages in the translational research continuum as phases of implementation, researchers can design their research during the exploratory and design phases, both at a macro/translational level and at the micro/study level, with a goal that the research and implementation effectiveness are generalizable and scalable to the population level. It is critical that researchers build empirical evidence and make data-based decisions that promote equity and generalizability from the exploratory phase onward for Precision Health research to fulfill its translation to the population health level.

After adapting DIS conceptually for Precision Health research interventions, this study demonstrates how DIS can be applied for informing research policies, designs, and practices. Specifically, this study will use the Practical, Robust, Implementation and Sustainability Model (PRISM) to evaluate the contextual factors related to implementing HPR and biobanking research interventions for professional athletes in the US.[31] Theses contextual factors will include logistical issues as well as ELSI of both HPR and biobanking. This study will engage professional athletes (recipients) and non-athlete stakeholders (from throughout the research and sports industry) to participate in key informant interviews (KII) to assess the contextual factors and themes in a hybrid qualitative study.[33,159-161] Contextual factors will be related to

implementation outcomes to inform what adaptations will most likely promote generalizability for both the Alliance's HPR and the biobank.

Finally, this study provides the Alliance with recommendations for policies, procedures and study design adaptations that are likely to increase benefits and decrease potential harms for aspiring and professional athletes based on the interview data. It is expected that the stakeholder engagement of this study will inspire future, more iterative engagement that includes evaluating the impact of their engagement efforts. It is also expected that this stakeholder engagement will also facilitate data-driven adaptations to the research practices and policies that will promote diverse recruitment and facilitate the Alliance's goal of improving health globally by decreasing the prevalence and burden of musculoskeletal injuries and disorders.

CHAPTER 2: Methods

This study describes the *theoretical adaptions* required to apply DIS methods to inform the adaptation and implementation of Precision Health research biobanking to the context of precision sports medicine and human performance research.[37] At the heart of this work is the engagement of multiple stakeholders from diverse contexts within professional sports along with Precision Health researchers involved in HPR and biobank research implementation. The engagement project began with KII to provide insights into the views of professional athletes and their stakeholders about Precision Health research biobanking and inform future, on-going, engagement activities. The first aim describes the adaptation of DIS methods for research interventions to inform how DIS can be operationalized to inform the adaptation of a Precision Health research and biobank intervention.[37] The second aim explores the attitudes and beliefs of professional athletes toward HPR and biobanking by using hybrid qualitative methods that combines both structured (deductive) and unstructured (inductive/thematic) qualitative data analysis.[33] This study used an adapted DIS model, PRISM, to inform the data collection and analysis from the KII to explore how multilevel contextual factors influence KII attitudes and beliefs.[31,32] Grounded theory, inductive codes were also developed to explore participants' attitudes and beliefs toward HPR biobanking.[34-36] The third aim of this study was to conduct a qualitative exploration of the themes and contextual factors that may impact implementation of HPR and the biobank in order to provide the Alliance with recommendations regarding how to best engage diverse stakeholders to inform the adaptation of HPR studies and the biobank.

2.1 Theoretical Adaptation

Specific Aim 1

DIS methods are most frequently applied for clinical and community implementation of interventions with proven efficacy and effectiveness.[29] DIS methods are, however, agnostic to the intervention and can be applied to diverse types of interventions, populations, and contexts. Brown and colleagues distinguished various types of interventions that can be the subject of DIS activities.[162] They described these as the 7Ps referencing programs, practices, principles, procedures, products, pills, and policies.[162] For this study, the Precision Health research biobank is regarded as the intervention and can be conceptualized as a *product* in the 7Ps lexicon as it is a tool or resource that can help researchers accomplish their goals.[162,163] The operationalization of DIS methods to Precision Health research has been initiated in the integration with learning health care system and omics biomarker uptake, specifically related to diagnostic genomic test development.[144,147] This study expands on these studies by developing a conceptual justification that addresses each of the following issues: 1) Explain need for the application of DIS methods to Precision Health research interventions. 2) Demonstrate similarities in approaches and outcomes between DIS and Precision Health research. 3) Identify the adaptations to DIS methods required for application to a research context. 4) Justify the appropriateness of this application of DIS beyond implementation of evidence-based best practices.

This aim applied the methods outlined by Jaakola for designing a conceptual manuscript via the *theory adaptation* approach.[37] First, this aim describes the current problems: 1) Lack of methodology to guide designing and implementing Precision Health research interventions across diverse contexts, 2) Short-comings in integrating community engagement into Precision Health research study design and practice, 3) Lack of rigorous methods for evaluating community engagement, and 4) Lack of measurement of the effectiveness of various community engagement activities. This aim goes on to explain why DIS science is an appropriate theory for

Precision Health research and the potential value that it can add to this field, such as providing measures for community engagement activities related to implementation outcomes. This aim describes how DIS would need to be expanded to accommodate Precision Health research. For example, as most Precision Health research interventions are still research, the ideas of fidelity and effectiveness need to be broadened beyond evidence-based practices to allow for the inclusion of purely research interventions, such as biobanks. Examples of potential applications of DIS in Precision Health research are provided, such as implementing genomic testing in the clinical setting and biobanking research interventions.

This aim justifies the expanding of the application of DIS theory to include implementation of Precision Health research interventions. This aim describes how DIS methods can provide much needed empirical data on both the community engagement activities and the impacts of adaptations (also part of implementation strategies) to traditional research policies and practices.[37] In accordance with the methods for theory adaptation conceptual papers, this aim shows how the current practice of conducting community engagement in parallel to Precision Health research implementation results in a lack of incorporation of feedback into the design phase and a lack of rigorous methods and empirical data to evaluate outcomes related to the effectiveness of community engagement across diverse settings and communities.[24-27,37] The lack of rigorous reporting of engagement activities makes it difficult to plan for successful future engagement. A systematic reporting of engagement activities, modifications to research designs and processes, and assessments of the impact of both engagement and modifications related to community contexts could provide guidance to future researchers and empirical data to support decision-making in both best practices for engagement as well as inform future study designs and procedures. Building on best practices for community engagement to inform which engagement

methods are most appropriate for which contexts would likely benefit Precision Health researchers who themselves may not understand the impact that successful engagement can have on research implementation. t. By standardizing Precision Health research outcomes at both the study level and across the translational research continuum, DIS would enable researchers to amass empirical evidence that can allow for data-driven decision making in new and future studies.

Due to the long time commitments required for community engagement, Precision Health researchers also struggle to justify appropriate budgets due to the expensive bench and/or clinical multiomics research budgets.[25,27,71] DIS, however, structures community engagement activities as implementation strategies, thus allowing for the measurement of the effects of these strategies on research outcomes while capturing cost and evaluating potential impacts of adaptations.[23] DIS methods also measure the impact of these strategies on implementation outcomes: acceptability, adoption, appropriateness, costs, feasibility, fidelity, penetration, and sustainability.[23,164-167] This aim highlights the commonality in implementation strategies and outcomes between implementing complex evidence-based best practices and implementing Precision Health research interventions.

For Precision Health research biobanking, these outcomes are vital for success and require researchers to be receptive to feedback and able to change their research practices, particularly in the exploratory and design phases of research implementation.[106] This aim goes on to show how DIS's outcomes would be useful to the implementation of a Precision Health research biobank and that one must only revise one's perception of fidelity slightly to align it with Precision Health research. DIS methods identify a variety of implementation strategies that researchers can incorporate and measure the strategies' impact on various outcomes.[23,32,122,168]

Major implementation strategies include stakeholder education, engagement, and adapting interventions, which are the same community engagement strategies utilized by Precision Health research biobanking researchers.[28,168] With the ability to capture engagement data more rigorously, Precision Health researchers could optimize their research activities and share data-driven best practices .[68,106,167,169-172]

Another example is the systematic documenting of adaptations through which researchers can amass data on what individual or organizational characteristics are best suited for what changes.[28] For example, Precision Health researchers know that broad consent has been shown to be acceptable amongst affluent, well-educated, non-Hispanic White people, but uptake is significantly lower in other groups.[19] However, due to a lack of standardization and measurement in the field, the appropriateness of adaptation(s) to improve research participation has not been clearly demonstrated. By adding an assessment of cost, both of the engagement activities and of implementing adaptations, to the measurement of DIS outcomes (such as acceptability and ability to reach one's target population), researchers could begin to use existing data to determine the return on investment for various engagement strategies and adaptations. For example, researchers would be able to incorporate data-driven adaptions into their existing research infrastructure and understand the balance between the up-front cost to change their infrastructure compared to the impact on research participation rates. These measurement tools can also help identify both top priorities and priorities with low feasibility.[173] These potential future impacts of integrating DIS methods are be discussed and balanced against the need to change DIS methods and concepts to incorporate Precision Health research. In summary, this aim discusses the similarities in the processes and outcomes between DIS research and Precision Health research, justify adapting DIS methods to be used in research, explain how DIS methods can capture rich

information from stakeholders throughout the phases of implementation, and evaluate the impact of these activities and adaptations on research outcomes.

2.2 Operationalization of DIS for Human Performance Research Biobanking

Specific Aim 2a

Due to the novelty of using DIS methods for Precision Health research implementation, it was necessary to demonstrate in detail how these methods can be applied to the implementation of a Precision Health research biobank that includes multiple cohorts, stakeholders, and organizations. Therefore, the second aim of this study demonstrates how a DIS framework can be used to guide the assessment of the planning, development, and implementation of a recision Health research interventions across the implementation phases (Fig. 2.1). This aim describes the operationalization of a DIS framework, the Practical, Robust, Implementation and Sustainability Model (PRISM). PRISM is the contextually expanded version of the broadly used RE-AIM (reach, effectiveness, adoption, implementation, maintenance) framework. PRISM has been used across diverse contexts and can be used to guide the planning, design, and implementation of a new Precision Health research biobank that utilizes multiomics technology to study elite human performance (Fig. 2.2). This aim also demonstrates how DIS implementation outcomes (i.e., feasibility, acceptability and RE-AIM outcomes) can be assessed using the PRISM and RE-AIM frameworks throughout the implementation process to measure successful research implementation (Fig. 2.2).[23,31,32,130,131,135,174] It is expected that contextual factors will vary across the different proposed cohorts (e.g., military personnel, Olympians, children), so these frameworks were used to design the first phase of community engagement for this initial cohort: KII of professional athletes and non-athlete stakeholders. Although future engagement would likely have different non-athlete stakeholders, this modified framework is anticipated to provide

a structured methodology that would allow comparisons across cohorts. Specifically, this aim operationalized PRISM to demonstrate the operationalization of DIS methods to implement a Precision Health research biobank targeting multiple cohorts, stakeholders, and sites.[31,32,130] PRISM has been identified previously as appropriate for use in Precision Medicine initiatives.[32,147] PRISM guides the identification of multilevel contextual factors, such as characteristics of the intervention, the characteristics of participant(s) and the organization(s) or the implementation and sustainability infrastructure and external environment known to impact the uptake, implementation, and sustained delivery of interventions (Fig. 2.2).[31,32] Understanding these contextual factors can inform the choice of implementation strategies (i.e., matching key barriers and facilitators with relevant strategies that address or capitalize on these factors). These contextual factors can also be used to interpret the implementation and effectiveness outcomes, both positive and negative.[31,32] The RE-AIM framework then provides the measurement of implementation outcomes by assessing the reach, effectiveness, adoption, implementation, and maintenance (RE-AIM) of the intervention (Fig. 2.2).[32,130]

Figure 2.2 shows the details of how PRISM operationalized to the implementation of a Precision Health research biobank where HPR and biobanking are separate interventions, but the biobank is encapsulated within the HPR intervention. The upper section shows the various contextual factors based on the PRISM context domains and how they interact with each other and with the RE-AIM outcomes in the lower section.[32] Figure 2.2 shows how the intervention has been broken out into the two major components: HPR and biobanking research.

It is important when adapting the intervention to isolate which component and specific characteristic is driving the adaptation, such as has been theorized for the biobank alone in Figure 2.3. The biobank intervention characteristics (the collection, storage, and sharing of

samples and data) have been highlighted and compared with potential adaptations, measures, and implementation outcomes (Fig 2.3). For this study, the research biobank is being defined as the traditional/basic biobank that requires broad consent for future, unspecified research, allows the researchers to own and govern the samples and data as they see fit, future research does not provide individual or aggregate results to participants, nor are participants notified about future uses of their samples or data. The biobank's core functions are to collect, store, and share data and samples, and therefore, these functions are the traditional effectiveness outcomes that can be quantitively measured in the future throughout the implementation process (Fig 2.3). Figures 2.2 and 2.3 also show how this study proposes to assess the RE-AIM outcomes of reach, effectiveness, adoption, implementation, and maintenance.[32,130] Utilizing implementation outcomes allows the research team to evaluate the biobank's recruitment rates (traditional) and evaluate those who do not enroll (Reach implementation outcome; Fig. 2.3). By assessing reasons for not participating, the biobank could make data-driven decisions regarding potential adaptations to traditional characteristics against future changes in enrollment (Fig 2.3). Similarly, the effectiveness of the biobank's ability to share samples and data broadly can be compared to rates after adaptations to policies and procedures by analyzing how many research requests are denied that would have otherwise been accepted in the traditional model (Fig. 2.3). This model gives researchers the ability to assess more meaningful outcomes than basic effectiveness measures; thus, allowing researchers to choose diversity or quantity, for example, as priorities for their research implementation and iteratively measure success.

The intervention of HPR, on the other hand, includes the specific moonshots of the Alliance: Digital Athlete, Regenerative Medicine, Molecular Athlete, and Multiscale Athlete. Characteristics of HPR also include anticipated research results, such as personalized training or

decreased healing time. Participants in HPR may also be included in the biobank component as well, but they may or may not receive direct, personal benefit from their HPR participation or from the published study results. Other characteristics of the biobank and HPR have been included based on the existing literatures for both fields, such as broad consent and data and sample governance being controlled by the research team(s).

The intention/willingness of athletes or other end beneficiaries to participate in the Precision Health research biobank are anticipated to be informed by a set of multi-level contextual factors. PRISM can provide a structure to assess these multi-level contextual influences and examine how these interact with implementation outcomes.[31,32] As the bigger study may evaluate implementing human performance biobanking across a variety of cohorts (professional, Olympic, college, and children athletes; military personnel; older adults; individuals with musculoskeletal injuries; and the general public), it is important to clearly define the roles and characteristics of the major stakeholder groups. For all cohorts, the "recipients" are those individuals from the cohorts who would be recruited for participation and their legal representative when applicable for consent (e.g., the parents of a child).[31,32] However, inherent to the nature of HPR with elite performers is that there may be other stakeholders whose interests could also be impacted by individuals participating in Precision Health research biobanking. For example, among elite athletes, team management, coaches, agents, unions, and union representatives may influence the athletes' participation, either by encouraging or discouraging participation. These various stakeholders' perspectives are be considered, assessed, and organized under the 'organizational characteristics' of PRISM to help identify when barriers and facilitators to the research interventions are from those who might participate or from those in potential participants' spheres of influence.[31,32] This study also included the human performance

researchers as a stakeholder organization as they bring their own interests into who is recruited and how the biobank operates. Similarly, it is anticipated that some adaptations to the research interventions may not be pursued due to logistical concerns, and it will be important to account for these scenarios when evaluating the contextual impact on implementation outcomes.

Another factor that may impact implementation outcomes is the external environment.[31,32] For example, the funding source of the project may restrict what adaptations can be made to research practices. Similarly, other existing biobanks, such as the NFL, NHL, or Athlome biobanks, may impact perceptions of this new HPR biobank and may compete with HPR biobanking recruitment.[7] The external environment may also include society's reaction to this research or to information available about elite athletes, including the downstream benefits of the research to the general public. Media coverage of this research would also be a factor that would be included in the external environment. Other factors such as external research studies and commercially available products related to human performance may also color the perceptions of this research.

A specific scenario regarding the external environment might be that the philanthropic funders decide that all samples and data need to be shared with any researcher in the world for any research request despite an internally approved adaptation that allows participants to govern this sharing. In this case, the adaptation to the biobank would not be implemented and could have a direct result of decreased stakeholder perceptions of the biobank's acceptability, resulting in decreased reach of the research intervention into the targeted cohorts. This example shows how the contextual factors, implementation strategies (in this case, co-design), and adaptations can be organized and assessed throughout the various phases of implementation (in this case, design and implementation). Similarly, this example shows how contextual factors can then be linked, either

directly or indirectly, with implementation outcomes (acceptability and reach in this example). This example also demonstrates why it is important to document adaptations, both those accepted and rejected, that are requested during the iterative engagement activities. The tracking and measuring of adaptations have been described in DIS methodology to create scientific rigor and allow for on-going learning from the adaptation process itself.[144]

The implementation and sustainability infrastructure in PRISM includes the processes resources that are in place to facilitate the uptake, implementation, and sustained use of an intervention. They can be closely linked with specific implementation strategies.[31,32] For this study, these strategies involve various forms of community engagement that begin with key informant interviews (KII) that can guide researchers in selecting and conducting cohort-specific, appropriate, future iterative engagement activities (Fig. 2.1). KII may provide insights for researchers into what stakeholders view as potential barriers and facilitators to Precision Health research biobanking. This information can then be integrated into future iterative engagement that can discuss in greater detail how these barriers and facilitators may impact the research as well as what changes could be made to barriers to improve stakeholder buy-in. By discreetly tracking which stakeholder group requested a change, the reason for a change, and the result of the change (implemented or not), then this study can explore any downstream effects this change request had on research outcomes as well as costs.[28] Rigorous collection of these adaptations can help inform this study (e.g., engagement activities and outcomes across cohorts) and other researchers (e.g., other research biobanks considering implementation of procedural changes).[28] Furthermore, during this iterative engagement phase, DIS methods also provide methods for capturing additional qualitative data from engagement activities (e.g., meeting minutes, emails, field notes) for thematic analysis.[33,161]

2.3 Key Informant Interviews

Specific Aim 2b

Through KII, this study explored professional athletes' attitudes towards human performance and biobanking research and their perspectives towards research participation. To this end, questions sought to separate the HPR component from the biobank in order to isolate the unique characteristics, barriers, and facilitators to research participation for each research intervention. Athletes were provided explanations specific to the Alliance's research aims and asked open-ended questions about the two interventions to explore their knowledge, attitudes, and beliefs about the potential impact these research interventions may have for competitive, professional athletes in the US. As most professional athletes were aspiring athletes in their childhood and college ages, athletes and non-athlete stakeholders were asked to address how these interventions may have been perceived differently across the course of their lives as athletes. This study explored active and retired athletes', men's and women's sports, and team and individual sports to gather a wide variety of perspectives. The study also explored the attitudes and perspectives of other relevant stakeholders' (team management, team physicians, player agents, and player unions) as these stakeholders are a part of the context in which the athletes' make decisions about participation in a Precision Health research biobank.

Athletes were also asked to identify what parties or stakeholder groups should be included in the decision-making process for how this research is conducted. Contextual information about potential power dynamics and conflicts of interest were also sought to guide the selection and conduct of more iterative, future engagement activities. By understanding the context and organizational factors of the existing stakeholders, the KII can inform how community engagement could function to ensure equitable representation of stakeholder voices,

particularly the athletes themselves.[63,175] Using these KII, this study explored the existing power dynamics, expectations related to research outcomes, and possible ways to mitigate anticipated conflict to direct the composition, conduct, and procedures of the community engagement.[159,160,176] For example, professional athletes and their stakeholders may be invited to be a part of a Community Advisory Board to assess the research practices and policies and adapt the research study design to make it more acceptable to this cohort.[63,112,175] However, the literature suggests that modifications to the process of conducting a Community Advisory Board may need to be adapted to emphasize more active advising versus the more traditional, passive reviewer roles in the Advisory Board, and by making this change, researchers ensure the athletes' have more decision-making power.[63] Such a change can also help to ensure emerging sports have equitable representation and/or determine if there are fundamental differences in athletes' experiences that require more individualized approaches or multiple Community Advisory Boards (e.g., to address contextual factors faced by team sports that are not applicable to individual sports).

KII Recruitment and Retention

As this study seeks to inform research protocol and policy development, it was imperative that this study conduct interviews with a wide variety of stakeholders in a timely manner. As it was also expected that recruitment of professional athletes would be very difficult, this study was designed to ensure feasibility in conducting interviews and reporting study results in a timely manner to allow these results to inform research implementation. To this end, this study chose to recruit key informants.

Key informants were identified as individuals who can offer greater depth of information due to their position in their community or who are members of a priority group, for this study

this would be professional athletes.[159,160,176] For this study, key informants of stakeholders associated with professional athletes in competitive sports in the US were recruited. Professional athletes in the US carry celebrity status and are thus often insulated from the general public via numerous non-athlete stakeholders, such as the athlete's agent, personal trainer, team physician, and union representative. Anecdotal information indicates that professional athletes rely heavily on the opinions of these non-athlete stakeholders when making decisions that may impact their careers. However, it was unknown which stakeholders would be critical groups to include in discussions with the research team to inform how these studies should be designed and conducted. Therefore, this study recruited participants from these two main categories: professional athletes and their related non-athlete stakeholders. *A priori non-athlete* stakeholders for this cohort include agents, union representatives, team managers, owners, physicians, trainers, and researchers. However, during the interviews this study asked participants to identify key stakeholder groups and iteratively expanded the non-athlete stakeholder cohort according to participant feedback. Examples of other stakeholders identified from the interviews included mental health professionals and lawyers who were not also agents.

To focus recruitment of professional athletes and their non-athlete stakeholders, this study prioritized enrollment to those stakeholders who have experience in more than one role, such as agents who were also former athletes, and stakeholders with unique characteristics that may enrich their ability to speak about the major barriers and facilitators to conducting HPR biobanking with professional athletes, such as an athlete who has a medical degree. However, the sample size was based on grounded theory best practices to allow for an analysis of two independent groups, those who are professional athletes and non-athlete stakeholders.[34] As is emphasized by the definition of key informants, these participants are anticipated to provide

richer data than a sample of the general target population.[159,160,176] The greater depth of information offered by key informants can also better facilitate informing research study designs and policies as it is expected that trying to recruit from the general population of professional athletes in a timely manner would not be feasible and would significantly delay beginning HPR and biobanking.. This study anticipated that recruitment of 20 professional athletes, active or retired, and 20 non-athlete stakeholders would allow a wide variety of voices to be heard while also reaching data saturation. Nonetheless, this study recognized the need to challenge *a priori* assumptions regarding which non-athlete stakeholders should be recruited, so this study built-in flexibility and funding to recruit up to 30 members of each group as new stakeholders may be identified during the interviews.[34] . A sample size of 20-30 participants per stakeholder group was determined to be appropriate for a grounded theory approach.[34] However, also in accordance with grounded theory, this study planned to end recruitment in the event of data saturation, which is the point where there are no longer new insights gained in the interview process.[34]

This study anticipated 40-45 KII interviews would be sufficient for data saturation across the various stakeholder groups. Although there were a number of stakeholder characteristics being considered (such as men's or women's sports, active or retired athletes, and types of non-athlete stakeholders), the strength of this study is that in seeking out key informants, a smaller sample size can be anticipated as the depth of data from each participant is expected to be richer.[160] Again, the choice of key informants was critical for the success of this study due to the anticipated difficulty of accessing members of this cohort. Similarly, due to these individuals being key informants and inherent purpose of qualitative research, this study did not seek to generalize findings about the various characteristics represented. For example, this study was not intended to assess differences between subgroups, such as perspectives of retired versus active

athletes, women's sports versus men's sports, or coaches versus agents. However, variations in contextual factors related to the athletes' environments and/or experiences that may impact research participation are reported herein. Instead, this study fills the gap in the literature about perceptions of professional athletes about HPR and biobanking while also providing rich contextual information and perspectives from other non-athlete groups who are expected to have a stake in HPR biobanking of professional athletes.

Stakeholders were identified from publicly available information (purposive), research team member experiences (convenience), and via key informant interviews (snowballing). Purposive sampling is a cornerstone of qualitative methods, particularly for key informants, as this method helps the researcher choose participants who can best help the researcher understand a wide range of issues, and thus, this sampling technique was used to recruit stakeholders throughout the process.[34,177,178] Stakeholders who represented more than one group, such as coaches who were athletes, were prioritized for their increased depth of knowledge. Priority was also given to those who have unique qualifications that are believed to enrich the data collected (e.g., stakeholders with medical or law degrees) or those believed to have unique risk profiles for participation in Precision Health research biobanking (e.g., professional athletes from historically underrepresented or marginalized groups). Although purposive sampling can identify true key informants, a major drawback to this sampling method is that this cohort may be very difficult for researchers who are outsiders to access specific individuals.

One way this study sought to address this barrier was to use convenience sampling by requesting recommendations from other researchers, community members, or other stakeholders.[178] Convenience sampling allowed the research team to leverage connections within the Wu Tsai Human Performance Alliance network to connect to a broader network of

professional athletes and non-athlete stakeholders. The research team also identified potential key informants via snowball sampling, particularly for professional athletes as personal connection was critical for gaining access to this exclusive group.[178] It is known that convenience and snowball sampling introduce bias as those recommended are likely to share similar views as those who are already engaged in the research. Therefore, snowball sampling was done by asking participants to recommend key informants either within their stakeholder group or in another group and asked participants to identify people who held different views or had different lived experiences. This study also asked researchers, community members, and participants to connect the research team to other races and ethnicities beyond non-Hispanic White in order to recruit a diverse range of perspectives. To further avoid sampling bias, recommendations were prioritized using the same criteria outlined in the purposive sampling.

Interviews were focused on individuals' opinions about professional athletes participating in HPR biobanking, and the results of the interviews generally tend to be focused on this one major theme that includes rich context and a wide variety of perspectives. Including key informants who can provide deep context and can contrast priorities between stakeholder groups is another strength of this study design despite these key informants not necessarily being representative of the general characteristics and experiences within this cohort.[159,160,176] This choice of key informants is expected to provide a greater depth and a wider range of perspectives that can inform future directions, such as determining what key questions may be needed in a survey of athletes or what key topics should be discussed first in greater depth with stakeholders.[159,160,176] This rich understanding of the context in which professional athletes are situated may be useful in the future for understanding differences between future cohorts. For example, the consideration of risks of discrimination for Olympic athletes who are paid via

endorsements compared to the risks identified by professional athletes who are paid directly for their athletic performance are expected to have different risk-benefit ratios. Similarly, those who are active duty or retired military are expected to have different risk-benefit ratios due to their past experiences with research, potential for loss of employment from unanticipated study findings, and the transparency of their medical records to their employer. These unique contexts should be explored through future research and can be used to compare and contrast contextual factors that may impact implementation of a HPR biobank. Similarly, these interviews provide rich context for future quantitative studies such as tracking discreet adaptations or generalizable surveys.

Furthermore, the information obtained from these key informants is anticipated to aid researchers by filling a gap in the literature while also informing where future research is needed, how research with these stakeholders is best conducted, and what questions are most appropriate to ask of a generalizable sample. As such, this study anticipates that the results of these KII were used to inform how iterative engagement and co-design may be structured to work with the critical stakeholder groups to design how HPR biobanking can best be conducted amongst professional athletes. This study also provides insights into what themes are specific to this cohort, what themes are believed to be universal across the spectrum of athletic development (from childhood through the their peak performance as professionals and, in some cases, into retirement).

Active and retired professional athletes were recruited, and this study attempted to recruit men's and women's athletes equally. The study also sought to include both team and individual sports to inform how future community engagement recruitment and activities should be balanced. Non-athlete stakeholders included agents, lawyers, players' association

representatives, coaches, trainers, and team staff, including physicians. Other human performance researchers from within the Alliance were also recruited as stakeholders to participate in this study in order to understand the organizational characteristics of the researchers themselves. During the recruitment process, mental health providers were also identified as important non-athlete stakeholders and were also recruited, which included private and team sports psychologists. All participants were compensated up to $100 for the one-hour interview.

KII Data Collection

Interview guides were based on the PRISM framework to assess organizational and participant perspectives of the two research interventions (HPR and biobanking research) in addition to capturing characteristics of these stakeholders (Table 2.1). The PRISM framework also includes questions for the various domains linked to various stages of implementation, such as planning and governance.[31] For example, in the development phase, the framework advises addressing within the Program Intervention- Patient Perspective domain "Does the program address important patient barriers to response?"[31] A major aim of this study was to understand the barriers and facilitators faced by potential participants when implementing a Precision Health research biobank. Both the domain and the study aims were identified in the data as structured codes, see below for more details.

Key informants were asked to discuss how future engagement for this cohort should be designed. To do this, key informants were asked about existing power dynamics and potential conflicts that may exist between other stakeholder groups. This information can be used to determine the best way to engage these stakeholders to ensure the participants are equitably represented amongst the various other stakeholders. The interview guide for each cohort was

piloted and iteratively adapted to ensure the questions were understandable, face valid, and that the interviews could be completed in approximately one hour.

The interview guide in the Appendix Section 5.1 shows a sample of how PRISM domains and their subdomains can be mapped to RE-AIM outcomes (reach, effectiveness, adoption, implementation, and maintenance). After finalizing the interview guides, semi-structured interviews were piloted and reviewed by the research team to assess both the interviewer's methods and appropriateness of the questions. One-hour, semi-structured KII with professional athletes and their relevant non-athlete stakeholders were conducted and recorded via Zoom. Transcription of the interviews was completed using Rev.com, an industry leader in transcription services. Transcripts were spot-checked by the lead researcher, JC, to ensure accuracy. Demographic data were collected from participants at the time of the interview using REDCap.[179,180] Dr. Schrairer, a qualitative methods expert and member of the research team, reviewed transcripts throughout the study to ensure that interviews were being conducted in accordance with qualitative methods' best practices.[34,181,182] These audits helped to minimize the introduction of bias by the interviewer into the study by providing real-time feedback when issues arose. Furthermore, these audits helped to inform the interviewer when additional probing may be warranted to help ensure that the final dataset is robust.

Data coding and analysis

The interviews were coded and analyzed using ATLAS.ti 23.[183] Transcripts were grouped as 'professional athlete' and/or 'non-athlete stakeholder' to allow thematic analysis across stakeholder groups, including those who represent both stakeholder groups. A hybrid approach guided coding of the transcripts that consisted of deductive structured codes using PRISM and inductive codes that were based in grounded theory methods.[31-36] All transcripts were reviewed

for accuracy and any identifying information was redacted. Transcripts were systematically coded following common methods in qualitative coding.[184-186]

The structured codes captured the major contextual domains (recipient, organization, and intervention characteristics, external environment, implementation strategy and sustainability infrastructure) and the implementation outcomes (reach, evaluation, adoption, implementation, and maintenance) from PRISM (Fig 2.2).[31,32] The structured coding was completed by the primary investigator (JC) throughout the study recruitment phase, and a minimum of 15% of the interviews were reviewed by a DIS expert, Dr. Borsika Rabin, with the primary investigator for consensus of the accuracy of coding. Following any changes that arose during consensus coding meetings, the primary investigator reviewed all previously coded transcripts to ensure any changes in coding methods were applied consistently to the other transcripts. Structured codes were later used in conjunction with the major themes direct reporting back to the study's aims: to identify the expected outcomes of this research, barriers and facilitators to recruitment of professional athletes, identification of key stakeholder groups, and to understand how researchers should engage with these stakeholders in future, iterative, community engagement to modify research policies and practices. By including the aims and PRISM domains as structured codes, this study provides a framework for deductive analysis with future cohorts, different contexts, and potentially across multiple biobanks. These structured codes also facilitated the organization and prioritization of results reporting.

The transcripts underwent a thematic analysis at the conclusion of the interview process. Following the conclusion of recruitment and interviews, the primary investigator worked directly with Dr. Schrairer (CS) to review selected transcripts for themes to build a working codebook. Codes were created by iteratively reviewing major concepts identified from the selected

transcripts. The codebook was developed by continuing this process until such time both researchers felt all major concepts were captured. Consensus coding was done by both the primary investigator and the qualitative research expert, CS. Full consensus coding was conducted on each transcript until such a time that both researchers believed consistency had been achieved. Coding was then conducted iteratively such that each of the coders would code two manuscripts independently and every third transcript would undergo a full consensus coding process together. A minimum of a third of the transcripts underwent full consensus coding across the entire inductive coding process at regular intervals, to ensure codes are applied consistently. New themes and modifications to the definitions required all previously coded transcripts to be recoded to include the changes.

Following the data coding, the data were analyzed in an iterative process in an attempt to identify major themes and important considerations related to research implementation. The data analysis sought to identify thematic insights and variability with regards to participants' knowledge, attitudes, and beliefs of these key informants. Reporting focused on major barriers and facilitators to both HPR and biobanking. By using reflexive inductive methods alongside the deductive methods of applying PRISM domains, the research team sought to minimize bias by imposing preconceived meaning from either their own beliefs or ideas presented in the literature.[34] This analysis was not intended to identify generalizable truths about any of the stakeholder groups nor can it be generalized beyond these participants. Instead, this study sought to provide a holistic account of the complex context into which HPR and biobanking were to be implemented and to better understand the multiple perspectives that may emerge.[34] Furthermore, this study used the information provided by these stakeholders to inform future, iterative

engagement activities, as well as provide policy, research design and research conduct recommendations.

As part of the analysis process, the researchers regularly needed to reflect on how their background impacts both the design of the study and interpretation of the data.[34] This is another opportunity to identify bias as well as to inform future research considerations.[34] As this research seeks to describe and interpret a new area of research in understanding how US professional athletes perceive HPR and biobanking, this study was focused on understanding the context and cultural schemas that US professional athletes operate in and into which a future HPR biobank would be implemented[34,35,187,188] Furthermore, this analysis helps researchers understand the interpersonal relationship between key stakeholders and interorganizational relationships, both of which were critical components for successful implementation of an intervention (either clinical or research).[189] In addition to providing recommendations to the Alliance focused on key considerations and potential adaptations to traditional research practices, this qualitative data is expected to also help triangulate and add meaning to future quantitative outcomes measures, such as enrollment rates, as well as inform future survey development to explore themes in a more representative, and thus more generalizable sample.[32,34]

Analysis employed a hybrid approach that included inductive coding based on grounded theory to allow for themes to be identified directly from the transcript data while also applying deductive, structured codes based on the constructs from the PRISM framework (Fig. 2.2 & Table 1).[31-36,161,181] By incorporating these DIS frameworks into the data analysis, themes, and ultimately implementation outcomes can be compared to future cohorts and capture changes over time. Additional information about human subject protections and procedural details can be

found in the Appendix Section 5.3 IRB Protocol. Similarly, interview guides for athlete and non-athlete stakeholders have been included.

2.4 Figures and Tables

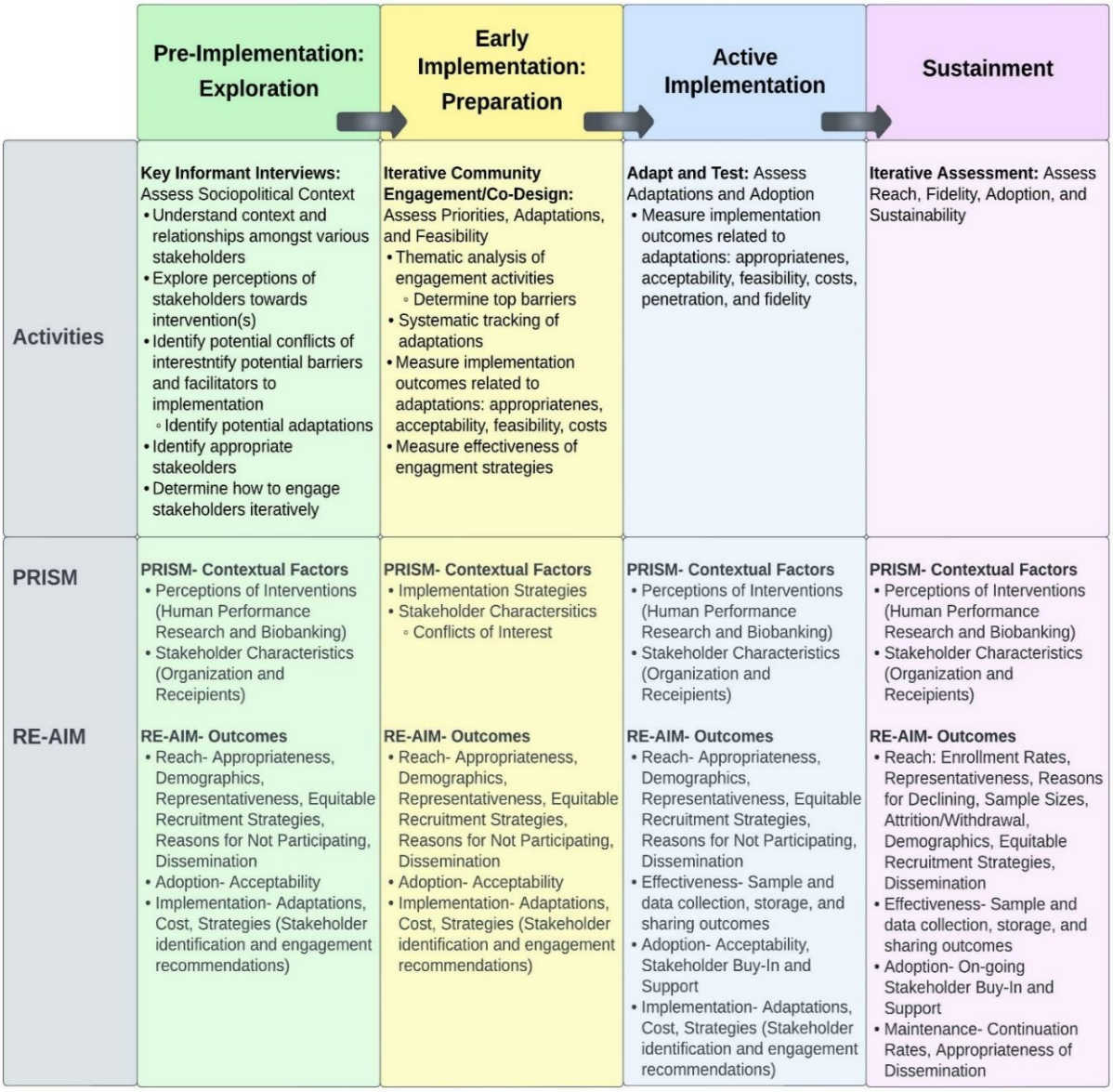

Figure 2.1: Application of PRISM across Implementation Phases for Precision Health Research Interventions:

This figure describes how various research activities can inform the next phase of the research implementation while iteratively addressing and assessing the contextual factors by using the Practical, Robust Implementation and Sustainability Model (PRISM) and assessing implementation outcomes from the RE-AIM framework (a component of PRISM) that assess Reach, Effectiveness, Adoption, Implementation, and Maintenance of the research intervention(s). Implementation process stages adapted from Aarons, GA., Hurlburt, M., and Horwitz, SM. (2011).[121]

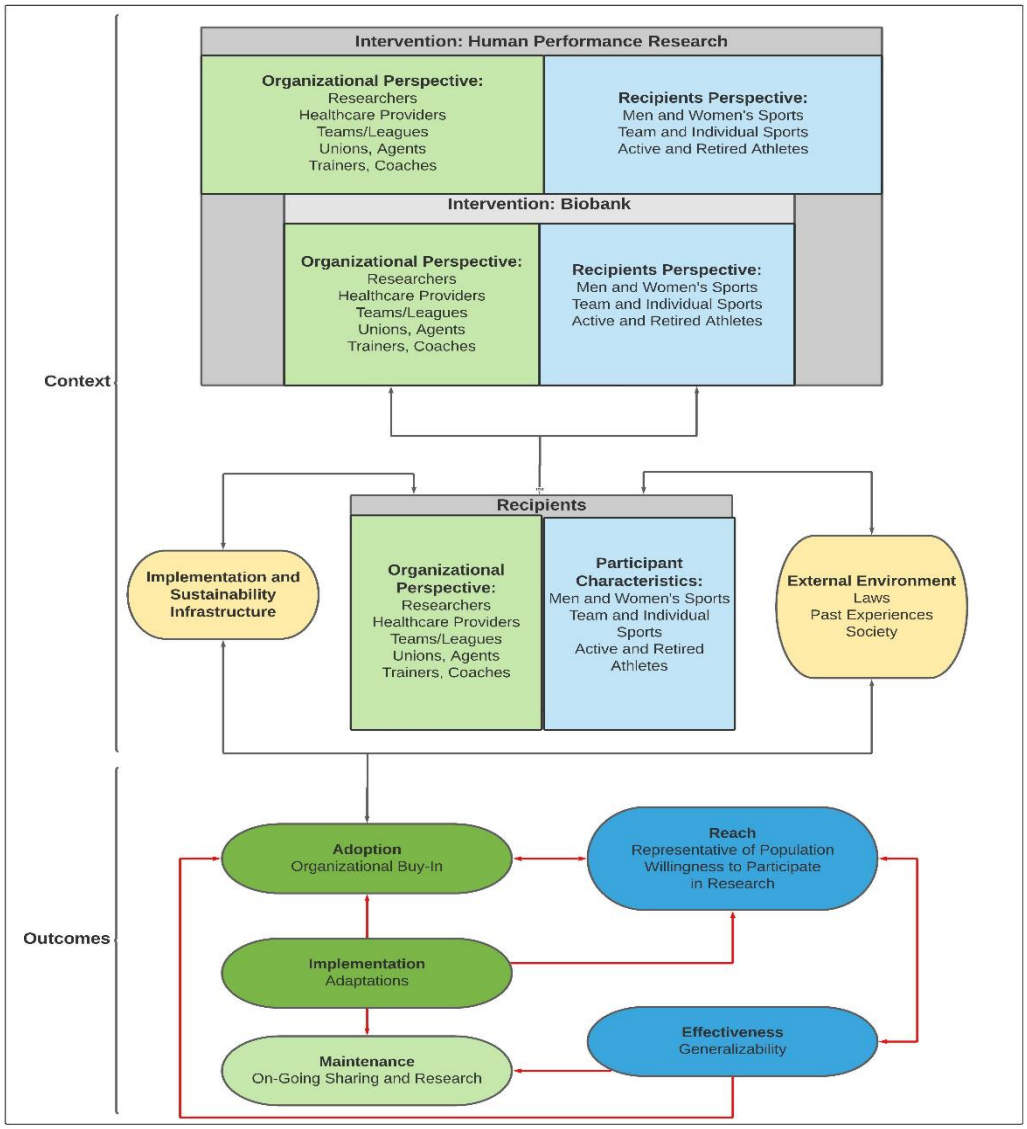

Figure 2.2: Adapted PRISM framework for Implementation of Human Performance Research and Biobanking Research Interventions:

This figure adapts the original PRISM framework to include an assessment of both human performance research and biobanking as separate and connected interventions. Recipients in this study are professional athletes in the United States who would likely be eligible for participation in these two interventions. External Environment includes legal protections, historical and existing experiences related to human performance interventions, and societal factors. As shown in the framework, these external factors impact both the recipients and members in the organizations. The Organizational level includes the researchers themselves as well as non-athlete stakeholders who work closely with the athletes (agents, team staff, healthcare providers, unions, and other support staff). The pathways of change in implementation outcomes have been changed to reflect the prioritization on generalizability, which requires an increase in diverse research participant recruitment (Reach). Improvements in organizational buy-in (Adoption) are anticipated to improve the study's recruitment. As recruitment becomes more generalizable, it is expected that both research interventions will be more Effective, which will have a positive feedback loop of increasing Reach and Adoption. This positive feedback loop is anticipated to increase the Maintenance of the study as participation becomes more acceptable throughout the community.

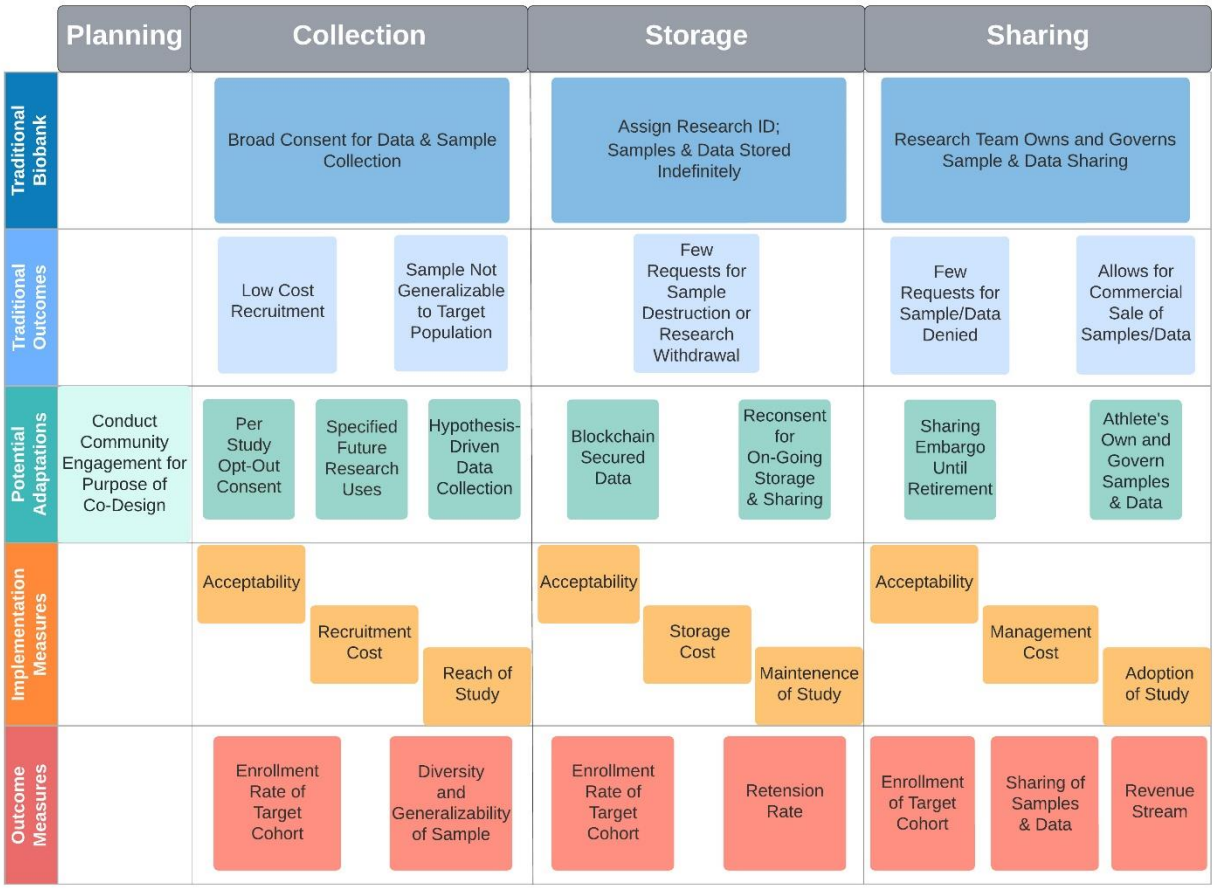

Figure 2.3: Biobank Processes and Potential Adaptations and Implementation Measures:

Implementation of the human performance research biobank involves the following processes: planning, sample and data collection, storage, and sharing. Traditional biobank processes and outcomes are contrasted to adapted biobank processes with implementation-related and enhanced outcome measures.

Table 2.1: Preliminary Interview Questions Mapped to PRISM Contextual Domains and RE-AIM Outcomes

Domain	Subdomain	RE-AIM Outcome	Sample Question
Intervention-Organizational Perspective: Human Performance Research	Ability to Observe Results	Adoption	"*What benefits can you imagine human performance research could have?"*
Intervention-Recipient Perspective: Biobank	Addresses Participant Barriers	Reach	*"What are reasons why you would <u>not</u> want to participate in this kind of research?"*
Recipients-Participant Characteristics	Knowledge and Beliefs	Implementation	"*Over the course of your career, do you think your willingness to participate would have changed at different stages of your career path? If so, how and why?"*
Recipients-Organizational Characteristics	Shared Goals and Cooperation	Maintenance	*"Who do you think the research team should work with to make decisions about how athletes' samples and data are handled?"*

CHAPTER 3: Results

Note: This study is anticipated to produce multiple manuscripts, specifically a manuscript for adapting Dissemination and Implementation Science for Precision Health Research interventions (Section 3.3) and generalizable results manuscript (Section 3.2). Lastly, this study produced a White Paper for the Wu Tsai Human Performance Alliance leadership. For ease of reading the dissertation, the key informant results for both the generalizable results and the White Paper have been included in this section with minimal discussion. Drafts of the generalizable results manuscript and the White Paper have been included in the Supplemental Materials.

3.1 Theoretical Adaptation Manuscript

Title: Improving Precision Health Research by Prioritizing Implementation: How Implementation Science could advance research implementation during the exploratory and design phases of research interventions

3.1.1 Background and Significance

This manuscript employs the methods described by Jaakkola (2019) for how to design a conceptual theory adaptation paper to adapt DIS for implementation of Precision Health research interventions, specifically aimed at the exploratory and design phases of research.[37] Specifically, this manuscript will describe the existing problems in Precision Health research and then propose how expanding the application of DIS to research interventions could help to address these problems.[37] Finally, this manuscript describes how constructs in DIS can be reconceptualized to apply more broadly to both study-level implementation and across the translational continuum; this manuscript demonstrates how this DIS could be applied to exploratory research, including Research-Enhancing interventions, through first in-human research .[37]

Precision Health research has been largely focused on an individual-level and focused on disease states, typically referred to as Precision Medicine.[1] As Precision Health evolves into states of extreme health and expands into the population-level, logistical, ethical, legal, and social implications new and old will determine its success or failure.[79-85] Some of the current problems facing Precision Health's transition to the population-level is a lack of diversity amongst the existing research participants, distrust in researchers, lack of meaningful benefits for marginalized communities, and equitable scalability of interventions due to access and health disparities.[79,84,85] General consensus in the social sciences advises that researchers need to be more engaged in their communities to improve research acceptability and accessibility.[45,51,59,65,67,68,86] High-quality engagement, however, requires community feedback to be incorporated into research design, but often engagement is conducted much closer to the implementation phase rather than in the exploratory and design phases.

The Problem

It is no longer enough to produce efficacious research that is not representative and therefore not generalizable.[43,51,152,154,190,191] Precision Medicine, like biomedical research, has an on-going problem of lacking diversity, and the transition from disease to health in Precision Health will bring new logistical, ethical, legal, and social implications.[41,152,154] Marrying these new implications with the need for research to be inclusive in order to be generalizable is crucial to addressing existing health disparities. Precision Health research must learn from the past and make a concerted effort to incorporate and promote equity and generalizability over mere homogenous efficacy. To do this, general consensus in the social sciences advises that researchers need to be more engaged in their communities to improve research acceptability and accessibility.[51,59] High-quality engagement requires community feedback to be incorporated into

research design. Despite the iterative feedback loops within the linear pathway of biomedical Levy's Arrow, or translational research continuum, Precision Health research, like its founder Precision Medicine, remains siloed.[192]

For simplicity, this paper separates the five phases of the translational continuum into three: Life Sciences (basic research or T0), Clinical (translation to human through clinical practice or T1-T3, with emphasis on T1 and T2), and Population Health (precision public health or T4).[158,193,194] Transition points between the phases are supposed to be iterative processes that facilitate transitions between phases.[158,193,194] However, these phases have arguably become siloed, and the transition points have been described as "valleys of death" that impede advancements across the phases of translational research (T0 to T4).[192] However, the iterative process between the phases of translational research often fail resulting in silos.[192] Each silo sits on the translational science pathway, and although some interactions occur, the pathway has yet to be integrated into a cohesive process. Building on the breakdown between phases, we also see a lack of community engagement prior to T2, the translation to patients phase. As a result, precision public health fails due in part to the homogeneity promoted along the earlier stages, a lack of integration throughout the full process, and a lack of engagement in the exploration and design phases.[85,195]

Precision health relies on Big Data, and scaling from the individual to precision public health relies on representative Big Data.[79,82,196] However, for translation to Population Health, the Big Data needs to be representative in order to be generalizable, a problem inherited from Precision Medicine.[79,152,197] Underlying these silos is a Research-Enhancing infrastructure that generates Big Data but often is not considered to be *research* itself and is instead viewed as a means to facilitate future research. This infrastructure includes data repositories, biobanks, and

more complex systems that extract medical record data (such as learning healthcare systems), and as representatives samples are critical for Precision Health research to be effective at the population level, this manuscript will include these forms of research-enhancing activities as research intervention. Similarly, due to the lack of data supporting Precision Public Health at this time, this paper focuses on the earlier exploratory and design phases of the biomedical research continuum to recommend a new conceptualization and methodology that can redress these problems and ultimately promote the transition of Precision Health to the population level.[83,85]

A Possible Solution

It is not a new recommendation to integrate DIS into translational research, but integration frequently occurs only at the Clinical stages and still fails to translate into public health impact.[144,145] We argue that the incorporation of DIS into all phases of translational research as well as individual studies can provide researchers with a framework to evaluate the various contextual factors that will impact future implementation in phases T2-T4. DIS allows researchers to apply a common language and qualitatively and quantitatively assess implementation outcomes that go beyond research efficacy from T0 through T4.[144,158]

DIS also brings terminology to define the phases of implementation: Exploration (exploratory), Adoption/Preparation (design), Implementation, Sustainment.[121] In addition to these phases being applied to an individual study, these phases can conceptually be mapped to the translational research continuum where Life Sciences (T0) and Research-Enhancing tools are in the exploratory phase. T1 and T2 studies that introduce basic research to humans are in the design phase. More traditional applications of DIS occur at T3 or introduction to clinical practice and T4 expansion to the population level, where efficacy was previously obtained in T1 and T2 trials. Therefore, T3 and T4 research studies are in the implementation phase and once

established as routine practice move into Sustainment. As many studies have already begun to adopt DIS during the T3 phase, clinical implementation, , this paper will focus on the often neglected research interventions in the early stages (T0-T2) where interventions are being tested for efficacy through the first in human studies (T2), which are often in a grey zone between research and clinical, and community engagement is often just begining.[144,158,198-202]

By integrating DIS into the exploratory and design phases of research, researchers will have tools to measure and evaluate the contextual factors as well as the impact that adaptations made to their research designs and practices have on implementation outcomes.[28,29,133,135,144,147,156,157] One group of researchers has already begun using DIS for biomarker research in the T0 phase and mapping Precision Medicine factors along the translational research continuum to DIS strategies and outcomes.[147] This paper seeks to build on this foundational work and the work of Chambers et al. 2016 who expanded DIS to Learning Healthcare Systems to explore how DIS can be adapted and better conceptualized across these early phase research studies.[144,147] By conceptualizing all stages in the translational research continuum as phases of implementation, researchers can design their research at all exploratory and design phases with a goal of research and implementation effectiveness where interventions are generalizable and scalable to the population level.

As Precision Medicine has shown the clinical- and population-level impacts that a lack of diversity and ultimately lack of generalizability can have, the evaluation process throughout the phases should promote equity, address health disparities, and seek generalizability for translational science to achieve population-level implementation.[41,43,51,133,134,152,154,174,190,191,203] By building a body of evidence that assesses the effectiveness of adaptations in terms of return on investment, the research community can begin to make data-driven decisions about what

changes and strategies are most helpful in improving the acceptability and accessibility of Precision Health research, particularly for marginalized and historically underrepresented communities.[28]

As Big Data is also a critical piece of Precision Health research attaining the population-level, it is important that Research-Enhancing interventions also be included.[80,82,196] Precision health research, which included Precision Medicine, has a wide variety of types of research interventions, many existing in grey-zones between research and clinical interventions.[43,137] Therefore, it is critical that each type of research intervention be evaluated separately for the entire implementation process (exploratory, design, implementation, and evaluation). Furthermore, it is important that the intervention's research efficacy is not the only measure of the effectiveness implementation outcome.

Using the Reach, Effectiveness, Adoption, Implementation, and Maintenance (RE-AIM) framework, successful evaluation of implementation also includes all five outcomes.[32,130] The Reach outcome assesses researchers' ability to enroll a representative sample of their target population, assessments of who is not included and factors impacting willingness to participate, including access, awareness, equity, and the appropriateness of the research. [32,130,135] Adoption refers to stakeholder buy-in necessary for successful implementation.[32,130] For example, if a Precision Health researcher is interested in developing a polygenic risk score (PRS) for a behavioral trait, the researcher should be speaking with clinicians who may ultimately be ordering such tests to ensure these stakeholders would be willing to use such a test. Maintenance looks beyond the research to assess whether the research intervention, such as a PRS clinical test, is still being used after the research study has ended.

Implementation itself assesses fidelity to the intervention, capturing and measuring adaptations and costs, and end-user's use of the intervention.[32,130] By adopting DIS into Precision Health research researchers will be encouraged to evaluate adaptations made during the implementation process, such as changes to recruitment strategies to improve diverse representation, to conceptualize and measure the impacts across all types of research interventions. Similarly, concepts of clinical- and patient-perceived utility of the research are prioritized equally with basic efficacy in RE-AIM, so it encourages researchers to incorporate community and patient feedback into the research design.[32,130] It is anticipated that community engagement activities will increase in frequency and complexity in parallel with research and development, thus allowing for early-stage research projects to assess simple opinions, such as overall acceptability, to ensure scientific funding is allocated for research that is ultimately acceptable to the target community. Furthermore, efficacious research that is deemed unacceptable to the community will never be effective as it will be barred from real-world implementation; therefore, early community engagement can inform whether efficacy studies are appropriate uses of limited resources, such as funding. The notion of fidelity may also need to be adapted with regards to research interventions that have not yet been proven efficacious.

Similarly, Effectiveness includes not only success rates but potential negative effects/unintended consequences, quality of life, economic factors, subgroup variability in effects, and systems effects. Similar to fidelity, research interventions may not have the same traditional measures of success, and this outcome may benefit from being adapted to fit a wider variety of research interventions. Therefore, we will describe the outcome of effectiveness as it relates to the major types of research interventions and how this outcome is expected to interact with other implementation outcomes.

3.1.2 DIS Adaptations

As DIS traditionally is applied for interventions that have previously been determined to be efficacious, the notions of fidelity and effectiveness must be adapted for exploratory and design phase research interventions.[29] As a reminder, fidelity refers to the ability to conduct an intervention as it was originally designed. Similarly, using the updated RE-AIM definition of the Effectiveness implementation outcome from R. Glasgow et al. 2019, "The impact of an intervention on important outcomes," which is usually the effect outcome of the original study in which efficacy was shown.[32] However, effectiveness also includes negative effects, quality of life, economic outcomes, heterogeneous effects, unintended consequences, and systems impacts.[32] As seen in the definition, the trial's efficacy and/or effectiveness is only one part of this implementation outcome. Therefore, each research intervention needs to be assessed for what components are anticipated to impact a study's effectiveness when implemented into healthcare or society.

Fidelity may not be applicable in early-stage research, but it can be a useful concept when making changes to research interventions. One research example from genomics is the use of a biobank (traditionally a research-enhancing intervention), which typically seeks to collect, store, and share health information and biological samples for future, unspecified research. Arguably, the best biobank would have samples and data from an entire population and facilitate as much future research as possible. Therefore, if one wished to change a biobank, its fidelity and effectiveness can be compared to these outcomes. Does the change increase or decrease participation, do more or less people withdraw from the biobank, is there an increase or decrease in future research using the biobank's samples and data?

To further demonstrate how DIS can be applied to research interventions, we have provided three use cases and discuss how Effectiveness can be conceptualized in these three cases.

3.1.3 Research Intervention Use Cases

Clinical Research Interventions

The first example is closest to traditional DIS intervention, and that is research studies in the clinical setting that either return research results to the medical record, such as genomic testing trials, or test a new treatment, such as gene therapy. These trials test the research efficacy of the research test or treatment, but they can be T1 or T2 studies. For these trials to be successfully implemented, they must capture the target population, successfully deliver a diagnosis or treatment, be acceptable to healthcare staff, cause no harms, assess benefits beyond the diagnostic rate or treatment success rate (such as quality of life and perceived utility from a variety of stakeholders), and add to the generalizable knowledge. Therefore, adaptations that improve the buy-in of key stakeholders, such as healthcare providers in this scenario, would increase the Adoption implementation outcome. An increase in intervention Adoption by key stakeholders is also anticipated to increase the study's ability to reach eligible participants, and therefore also increases the Reach implementation outcome. Similarly, changes made to improve recruitment of the targeted population and promote representative diversity in sampling (or oversampling of historically excluded populations) will increase the Reach outcome and are expected to *increase* the study's generalizability and by extension its effectiveness and/or efficacy. Thus, increases in the Reach implementation outcome will be associated with an increase in the Effectiveness implementation outcome. As previously indicated, community engagement is the most widely accepted implementation strategy to improve recruitment of

diverse populations, so researchers seeking to implement a Clinical research intervention should engage with patients early on to adapt their research intervention and or methods of recruitment to ensure equitable access.[53,59,60,64,65,67,69,87,106] The addition of DIS methods is expected to facilitate the collection of empirical data to both demonstrate the value that community engagement has on the full implementation process, from exploration through clinical sustainment, as well as the value perceived by the community.[121]Similarly, Adoption can be promoted by early engagement of clinical staff. These engagement strategies are common implementation strategies, and DIS also offers validated measures to address the research intervention's acceptability, appropriateness, and feasibility.[23,125,129,131] Bringing this altogether, not only do we have a roadmap that guides engagement, but we can make data-driven adaptations and measure outcomes beyond simple diagnostic or treatment rates. Adding implementation outcomes that can be applied at the study level as well as that can orient researchers to their place on the translational continuum is likely to translate the value of community engagement work for researchers who rarely work with human subjects. DIS brings rigorous frameworks, strategies, and measures that can be used to generate empirical data from engagement. By measuring and tracking the impact of adaptations made throughout the implementation process, data could then be used by future researchers to inform future study designs and improve engagement efforts.

Life Sciences Research Interventions

The next example of research interventions in Precision Health is Life Sciences interventions or bench research. These studies include, but are not limited to, multiomics exploratory research, genome-wide association studies (GWAS) and other statistical modeling,

and genetically modified plants, animals, and insects (includes gene-drives).[204] These studies may have future translational impacts, but the initial studies are exploratory in nature.[204]

For example, a gene-drive that seeks to genetically modify a mosquito to prevent malaria transmission may begin in an exploratory phase to determine if the genetic modification is possible.[204] However, upon successful modification, the next phase of the research would be to begin testing it in controlled environments, which is where much of this the research has stalled, and then ultimately release it into the wild.[204] Therefore, when considering the research intervention's implementation, the genetic modification is still in the implementation phases of exploration and design (T0-T1), and the ultimate implementation outcome is successfully releasing the modified mosquitos into the wild at the population-level (T4). In this example, the Effectiveness implementation outcome, a decrease in malaria transmission, would first require successful implementation into the wild.[204,205]

These studies are prime examples for why it is important to apply an implementation lens to the exploratory and design phases as contextual factors related to successful implementation may impact research design decisions in these phases. For example, many researchers successfully modified mosquitoes in the lab setting and conducted controlled tests, but they were met with local-, state-, and country-level resistance. Instead of deferring engagement until the pre-implementation phase, researchers could have obtained this feedback earlier and pursued options that were more acceptable to the communities who would be living with the genetically modified animals or insects.[205] However, this field of research continues to struggle with when and how communities should be engaged in the research process leading to the incorporation of community engagement as a fundamental principle in the relatively new Code of Ethics for Gene Drive Research.[206-208] Similarly, engagement has recently been recommended to begin in the

planning stages of the research and carried through the implementation phase to facilitate successful releases via field trials.[209] Failure to test this research in the field and ultimately deploy this technology at scale would ultimately render this work ineffective, resulting in a loss of hundreds of millions of dollars in research funding.[210] One study that sought community engagement early in the design phase determined that unconfined releases into the environment was not acceptable to the community allowing the research team to pivot their release strategy to explore confined releases.[211] In this example, we see that the research outcome of Adoption by the community is critical for the research's ability to test its effectiveness and ultimately implement this technology into the target community. Therefore, in addition to the proposals of adopting engagement into the planning and design phases, this Life Science field could benefit from adding the structured assessments of contextual factors as well as implementation outcomes that are available from DIS.[29] Furthermore, adding DIS methodologies can promote the equitable distribution of risks and benefits recommended by the proposed Code of Ethics.[132,133,135,208]

Drawing on examples from Precision Medicine, such as reference genome research and genome-wide association studies (GWAS), we again see that failing to incorporate implementation into the exploration and design phases have impacted the effectiveness of these research interventions. The first human genome cost roughly $3 billion dollars, and although costs have decreased with improved technologies, the genomics research community has relied on reference genomes from individuals with European descent for the past 20 years, making it impossible to properly classify heritable variability in humans.[212,213] Genomic data for GWAS relied solely on these reference genomes. Furthermore, participants in genomics research were also predominantly of European descent.[152] In this early, exploratory research phase, GWAS

benefited from having large numbers of samples from a relatively homogenous population to obtain statistical significance, but when these results were applied to the population level, diagnostic testing and treatments were unable to be equitably implemented.[191] For example, clinical, genetic-based diabetes tests in 2010 only reported on 1 of the 15 variants for Black or African-Americans despite the high prevalence of diabetes in these communities as reported in 2012.[191,214]

Many factors contributed to these disparities, but we argue that planning for clinical implementation in the exploration and design phases could have identified the need to assess heritability and representativeness of samples in bench research. As such, the generalizability and ultimately the effectiveness of these studies suffered due to the lack of sample diversity.[152,191] Again, adaptations in these earlier research phases that targeted improving genomics research's ability to recruit diverse samples would have improved the studies' Reach implementation outcome. Improvements in the study's Reach are expected to improve the study's generalizability and therefore improve the study's Effectiveness in implementation. Adaptations, again, require early community engagement and willingness to modify one's research designs.

Research-Enhancing Research Interventions

Underlying all of Precision Medicine research are what we refer to as research-enhancing interventions that include research interventions such as biobanks and learning healthcare systems. These are research interventions that may or may not have any direct contact with participants. For example, a biobank is a means of collecting, storing, and sharing health information and biological samples for future, non-human subjects research. These samples may be scavenged from leftover clinical testing, such as dried newborn bloodspots or excess tissue

from surgeries. In these two scenarios, researchers could obtain a waiver of consent to collect "de-identified" health information and biological samples. In cases where the samples were obtained for research purposes, consent was required from the participant. It was only following the Revised Common Rule in 2017, that participants needed to be notified of any potential whole genome sequencing that may occur in future research, although exceptions remain.[215]

One of the drivers of the lack of diversity in Life Sciences and Clinical research was due to the lack of diversity in biobank samples.[152,154,191,216,217] Diversity efforts in genomics and biomedical research more broadly have persisted largely due to distrust in the scientific and medical communities, particularly by marginalized communities.[45,48,50,52,60] The lack of interaction and transparency in biobanks does not facilitate trust.[45,60,71,218] As highlighted by the cries of "nothing about us without us," many marginalized communities are actively working to be embedded in research decision-making processes in order to prevent othering and harm to their communities.[59,67] However, these engagement efforts are often limited to Clinical Research interventions. Therefore, the burden of research effectiveness related to generalizability can occur in research interventions that are passive research studies. However, many biobank researchers have engaged with communities and are now exploring adaptations to traditional research practices, such as dynamic consent and returning results.[20,89,103,107,110,199,219,220]

Therefore, we can again look to engagement to inform how research-enhancing interventions can be adapted to improve diverse recruitment, which is anticipated improve the research intervention's Reach implementation outcome. Again, by extension, these adaptations will not only improve the Effectiveness implementation outcome of the biobank to support future research by collecting generalizable samples and data, but these improvements in Effectiveness will cascade through the translational research continuum.

Similarly, the newer research-enhancing intervention, learning health systems, also utilizes existing data and samples to facilitate exploratory research and accelerate changes to clinical practices.[144] These learning health systems "de-identify" health information and are therefore not required to obtain consent unless conducting genomic sequencing on samples. Some researchers have conducted community engagement and found that despite the promise of improved future healthcare, patients wish to be notified about the research use if not asked to consent.[55,137,221,222] Again, transparency and communication are important for these research-enhancing interventions to work.

Therefore, to ensure that future research studies that utilize these resources is efficacious and effective, these research interventions need to be considered as part of the exploratory and design phases of the implementation processes of future endeavors. Furthermore, these interventions have their own benchmarks by which to evaluate their research effectiveness. Both seek to amass large amounts of high-quality health information and biological samples (particularly for biobanks) and ensure the samples and data are representative of their population. Both need to store these samples and data securely and appropriately and ensure participants do not withdraw from the research. Finally, both interventions' main outcome is to share these samples and data broadly to facilitate future research to improve health. In short, these interventions can be judged by the quality and quantity of the data and samples and their ability to improve health via research along the translational continuum.

By planning for implementation in these research-enhancing interventions, researchers have the opportunity to evaluate what adaptations may lead to more generalizable and thus effective future research.[28] If we consider a biobank the limited context provided, we can see how an adaptation to traditional practices to improve transparency could reasonably be expected

to improve the reach of the biobank to be more inclusive and representative of the population as a whole. Adaptations that encourage autonomy, such as dynamic consent, can also increase transparency and are likely to be more receptive to marginalized communities. However, by transferring decision-making power to participants, it is reasonable to assume that the biobank will no longer be able to fulfill all future research requests and/or share all available samples and data as participants will sometimes choose not to participate. Therefore, biobank researchers must decide if they value generalizability as their primary Effectiveness measure or quantity via their ability to broadly share samples and data.

3.1.4 Conclusion

These three use-cases do not include all uses, adaptations, or implementation outcome variability. However, they demonstrate that the translation from bench research to clinical research is a continuous spectrum and that even researchers with no direct clinical research activities need to identify their place on the spectrum and make implementation decisions based on the future implementation of their work. Similarly, these examples show how DIS can be applied not only to the translational continuum but also to individual research interventions' implementation.

Moving Precision Health to the population-level, researchers are still limited in their abilities to conduct large-scale research on populations that are not of European descent. As this research moves away from disease and into various notions of health, new moral concerns should be expected. For example, fighting diseases has a clearer objective than implementing interventions that may move humankind towards less appreciation of differences and more emphasis on a state of perfection as defined by researchers alone. History has shown the dangers in science that moves in this direction, and marginalized communities, particularly those who

have long histories of suffering research abuses, are unlikely to participate. Without generalizable research, we widen health disparities and exclude swaths of our population from equally sharing in the benefits of health.

To protect against such repetitions of the past, translational research can greatly benefit from integrating DIS into the exploratory and design phases. We discussed how researchers in these phases can align their own research with implementation outcomes focused on future phases, but DIS also guides researchers on how to evaluate the context into which their research will ideally be implemented. This contextual evaluation will promote early and often engagement with future participants and the community to ensure that research is relevant, acceptable, and feasible. By collecting and sharing empirical evidence related to this engagement and evaluating the impact changes in research designs and practices, more Clinical, Life Science, and Research-Enhancing researchers will be able to make data-driven decisions to guide translational research towards population-level implementation.

The next section will demonstrate how DIS methods can be applied to the exploratory phases of both a Life Science and Research-Enhancing research intervention. The adapted DIS framework, PRISM, described in the Methods Section will guide the deductive analysis in this hybrid qualitative study, and the interaction of the inductive themes will be discussed in the KII Results.

3.2 Key Informant Interviews:

Note: Due to the multiple rounds of coding, some quotation numbers do not always progress in order from smallest to largest.

3.2.1 Recruitment Results

Of the 98 individuals nominated for this study, 48 (49%) were professional athletes. Nominated participants were reviewed for eligibility, and the individual who nominated a selected individual was asked to confirm that the research team may contact the nominee for recruitment. Of the nominated individuals, 25 (26%) were determined to be ineligible due to not meeting eligibility criteria: professional athletes paid directly for competitive sports and their associated stakeholders in the US. 73 (74%) were approved by the nominating party for the research team to move forward and contact the nominee directly, 4 (4%) actively declined participation, and 10 (10%) passively declined participation (unresponsive to recruitment requests). Ultimately, 42 (43% of 98) individuals were enrolled in the study.

Of the 42 total participants, 20 (48% of 42) were either active or retired professional athletes and 22 (52% of 42) were non-athlete stakeholders (Table 3.1). Of the professional athletes, 8 (40% of 20) identified as female and 5 (25% of 20) were still actively competing. Of note, the professional athlete cohort also represented 21 non-athlete roles as priority was given to key informants who represented multiple roles (Table 3.1). Within the Non-Professional Athlete participants, 33 roles were represented, with many serving in multiple positions throughout their careers.

Slightly more than half of the participants represented team sports (23; 55% of 42), although 9 (21% of 42) participants represented both team and individual sports (Table 3.1). There were 18 (43% of 42) participants who identified as female (Table 3.1). The race and

ethnicity of this study was primarily non-Hispanic White (37; 88% of 42; Table 3.1). Forty percent (17 of 42) had either professional or doctoral degrees, which is consistent with targeted recruitment of athletes who represented multiple roles (e.g., physicians and lawyers). Seventy-six percent (32 of 42) reported being willing to participate in future discussions about the design and conduct of this research (Table 3.1).

3.2.2 General Results

Note: To minimize duplication of results, this section is only reporting results not described in the White Paper Results but may include duplicate results for the purpose of connection to the DIS framework. The final manuscript for this section will highlight the DIS and inductive themes that are believed to be applicable to a broader audience. The White Paper, on the other hand, includes results targeted to the Alliance researchers for the purpose that they may make data-informed decisions regarding their research study designs and practices.

This exploratory study was intended to provide data to the research team and inform how HPR and biobanking policies and procedures could be adapted to improve the acceptability and accessibility of these research interventions for aspiring and professional athletes. This study identified a wide variety of logistical issues and ELSI of these two Precision Health research interventions (HPR and biobanking) that are presented in both the thematic and structured results. The implementation results will be presented by exploring the major barriers identified and various implementation strategies identified in this study as they relate to contextual factors and implementation outcomes. The thematic results are represented in the White Paper Results.

Themes

Iterative inductive coding identified twenty codes (Table 3.2). There were four major themes identified in this study: vulnerabilities of aspiring and professional athletes, questions of the impact of the research, direct benefits for participants, and the importance of empowering athletes in the decision-making process.

Vulnerabilities

Vulnerabilities include characteristics of the athletes themselves that impact their willingness to participate in research (see Athlete Characteristics in the White Paper Results for

detailed descriptions). These characteristics include resources, experiences being measured and evaluated, and variability in participation over an athlete's life course. Generally, participants viewed potential risks for research participation of professional athletes extended to aspiring athletes, so researchers recruiting athletes who may become professional athletes in the future should consider modifying their research policies and practices to account for future risks, particularly with regards to confidentiality and potential discrimination.

Another major vulnerability identified was related to the large amounts of athlete's health information already publicly available, athletes' celebrity statuses, legalization of sports gambling, and athletes' experiences with discriminatory practices using health information to devalue the athlete in negotiations (see Confidentiality and Discrimination in the White Paper Results for detailed descriptions). These factors increased both the likelihood and value of re-identification from research data, which would place team athletes in particular at a potentially higher risk for discrimination.

Research Effectiveness

Questions about the effectiveness of the research included its ability to be generalized to the public, the ability of the research to result in exclusionary practices in the sports industry, and its potential negative impact on athletes' mental health (see Impact of the Research in the White Paper Results for detailed descriptions). Another potential impact of the research was that it may exacerbate existing disparities, both locally and globally (see Disparities in the White Paper Results for detailed descriptions). The need for the research to be representative and diverse was raised by multiple participants along with the potential for this research to further exacerbate health disparities. Other questions related to disparities centered on whether the Alliance could equitably share data and samples with researchers worldwide, pointing to low resourced

researchers lacking infrastructure to utilize these resources. Finally, several participants discussed concerns related to eugenics, such as whether the purpose of studying elite athletes was to create a master race.

Direct Benefits

Most participants believed that for athletes to participate in this research, they would need to benefit directly from participation. Participation was described as a cost-benefit ratio where the costs were an athletes' time, energy, and relinquishment of private information and biological samples. Returning study results to athletes was a major perceived benefit expected from research participation (see Return of Results in the White Paper Results for detailed descriptions). However, athletes are also accustomed to the commercialization of their health information, name, image, and likeness (NIL), and being empowered to own and/or control the use of their information. As such, another component of direct benefits included consideration of the future commercialization of the research and how those profits may or may not be shared by participants (see Commercialization in the White Paper Results for detailed descriptions).

Decision-Making

In a similar vein to athletes' empowerment to receive direct benefit from the research, decision-making was an especially important theme identified by nearly all of the participants. Most participants indicated that the athletes should control both what samples and data they wish to contribute and how their samples, data, and research results should be used and shared in the future. For example, most athletes wished to consent for future research studies, particularly those requesting sensitive information (see Consent in the White Paper Results for detailed descriptions). Nearly all participants felt strongly that the athletes and their trusted stakeholders

should be engaged in informing and developing research practices and policies (see Engagement in the White Paper Results for detailed descriptions).

Implementation Results

This study employed PRISM to capture and evaluate how contextual factors (Characteristics of the Recipients, Organizations, and Interventions, the External Environment, and Implementation Strategies and Sustainability Infrastructure) may impact implementation outcomes (Reach, Effectiveness, Adoption, Implementation, and Maintenance).[31,32,130] The outcome of implementation, however, was not captured due to this study being conducted in the design phase and adaptations to the research and implementation strategies had not been chosen at the time of submission. The structured codes, definitions, and exemplar quotes are provided in Table 3.3.

This study identified three main barriers to HPR and biobanking interventions being acceptable to aspiring and professional athletes in the US: the need for return of benefit to participants, for strict confidentiality, and for athletes to control how their samples and data are used and shared.

Strict Confidentiality

Contextual Factors for Strict Confidentiality

Discussions about confidentiality took many forms in this study (see Confidentiality and Discrimination in White Paper Results for detailed results). For some participants, confidentiality was limited to the concept of anonymization of samples and data. Other participants voiced concerns about staff and external researchers intentionally leaking athletes' information and identifiable data. Most participants engaged in team sports focused on controlling access to athletes' health information, research data, and samples to prevent discrimination.

Participation in the HPR was usually well-received by athletes, but an Intervention Characteristic that was necessary was strict confidentiality of data and results. This quote is representative of a sentiment widely shared amongst nearly all participants.

> "I think that's [HPR biobanking is] great. I think the only thing could be, if somebody gives consent and they understand that their samples can be used for future tests, as long as it's anonymous." 30:58 Athlete and Non-Athlete Role

Many of the concerns about the need for strict confidentiality were related to the Recipients' Characteristics (athletes) and a combination of Organizational Characteristics (teams and leagues) with External Factors (the sports industry and societal factors). This combination between the External Environment with Recipients' Characteristics and Organizational Characteristics impacted how participants discussed anonymity and the potential to re-identify participants from "de-identified" data).

The External Environment included contextual themes such as increased amounts of athletes' health information that is publicly available, legalized sports gambling, and athletes' celebrity status. It was believed athletes' data may become a source of personal profit either through sale of the data, using the data for gambling, or for personal notoriety related to having access to celebrities' information. These issues were most succinctly described by a sports lawyer although these contextual factors arose frequently among interviewees:

> "So there's going to be a lot of concern about the athletes, about the keeping control over their health information and keeping it confidential [...] The big issue the players have there, the unions, is consent and confidentiality, and not having the data commercialized. This whole concern that people are going to sell this data for gambling, and so there are issues that surround that." 12:26 Non-Athlete Role

The perception among interviewees was that these factors appeared to increase the intrinsic value of the data and thus increase the desire to re-identify athletes. Due to the common

practices of publicly sharing athlete's health information, re-identification was discussed as only requiring a few statistics and/or demographics. This former professional athlete and now a scout described the ease of re-identification of elite performers from "de-identified" data being directly related to the athlete's unique skills and performance characteristics. This participant also alludes to the External Environmental factor related to the sports industry's practice of making large amounts of athletes' data publicly available data. Other examples were also raised that included equally small amounts of data to re-identify a person.

> "I could look at someone's pitch metrics and TrackMan data and just from knowing all that stuff on record, if you showed someone to me that's really good, I could say like, "Oh, that's probably Josh Hader, because his release height is really low, and his extension is really high. And he's throwing 97 at this spin rate." I would be able to do that." 33:46 Athlete and Non-Athlete Role

Organizational Characteristics applied most directly to teams and leagues in this context. Many participants reported that teams and leagues, particularly high-grossing sports, have large financial incentives to gain access to HPR data. Those affiliated with teams and leagues indicated that everyone benefits when athletes are healthy and performing at their best. However, those not working for teams and leagues felt that the data would primarily be used to devalue the athletes in contract negotiations and pointed to the historical context of advanced analytics. One agent discussed how confidentiality becomes more valuable the closer and athlete comes to being a professional:

> "I don't think the risk really comes until you start getting into a business setting, where information can be used to try to devalue you in a negotiation." 25:54 Non-Athlete Role

The team personnel were often aware of the perception that the front office has ulterior motives as exemplified by this quote:

> "We [a professional team] definitely want to do it to aid in the development or health maintenance of that player. It's not always viewed that way." 7:10 Non-Athlete Role

The Recipients' Characteristics included concepts of concern that information would be used against them both by teams but also by their competitors. Many athletes affiliated with high-grossing team sports shared concerns similar to that of the agent above that information may be used against them in negotiations (see the Confidentiality and Discrimination in White Paper Results for more discussion). However, athletes in individual sports also spoke about how their research data could be used against them in competition as described by a tennis player below:

> "If my opponent knew about it [my hypothetical increased risk for an injury], I think that they would go in being like, "Oh, sweet! If I do this, or make her move a certain way, will she get injured?"" 38:24 Athlete

Similarly, athletes were frequently described as being distrustful, short-sighted, secretive, and selfish; these traits were often described as being necessary to achieving their goal of becoming great. This was best summarized by an agent's advice to his clients:

> "I tell my guys to be selfish. Be selfish with family, be selfish with their bodies, be selfish with everything. Because, you have only a short period of time that you can actually perform. Playing in NFL, you're talking about an average lifespan of three years. So, within that lifespan, that time period, you got to give everything you got. And taking chances and risks, I just don't know if I could do it [recommend research participation]." 32:45 Non-Athlete Role

Implementation Strategies for Strict Confidentiality

One implementation strategy that was identified by many participants was to use consent to allow athletes to control how their samples and data are used and results are shared, which will be discussed in greater detail below in Control of Usage. Another method for improving research acceptability (Implementation Strategy) identified and supported by participants was to place an

embargo on sharing individual-level data, samples, and research results. This expert in data privacy discussed how encryption could be in combination with an embargo strategy to facilitate strict confidentiality.

> "And so, some of the ideas were you encrypt it all, no one can see it. Impossible. And that encryption wears off 30 years later. That's not an encryption, but basically like, it will become possible to see this data 30 years from now, 50 years from now, 100. […] It's called a data embargo. So, that's one possibility." 29:49 Non-Athlete Role

Several participants were asked about this strategy for protecting athletes against discrimination with hypothetical embargoes lasting until an athlete retires. Most thought this solution was reasonable and likely to alleviate potential discrimination concerns. However, one athlete wrestled with the desire to maintain their individual competitive advantage by not sharing the secrets to their success, which affected their willingness to participate in research (Reach), against a more altruistic desire to both help move sports' performance forward along with arguably a less altruistic motivation to have the best players on the field (HPR Effectiveness). To this latter point, this baseball player expressed concern that an embargo on data-sharing until an athlete retires may slow the progress too much (biobank and HPR's Effectiveness outcomes). Prior to the quote below, this athlete spoke about wanting to have the best players on their team, so sharing information is critical to advancing science and improving performance. However, they also felt compelled to keep their 'trade secrets' private to avoid putting themselves out of a job (Recipient Characteristics). Below they discuss this conflict in terms of how they would feel if they had participated in HPR and received a benefit. They describe how a compromise in the amount of time research data is embargoed may reconcile this conflict between helping oneself and helping others. Of note, during the interview, the idea of an embargo was described as locking samples and data in the biobank's vault for a specified amount of time.

> "I've gotten to this point and now I'm in self-preservation mode and to where I'm trying to give back to the game now. The vault [embargo] idea is good and interesting […] Because maybe I found this [HPR] study that helped me with my niche, and now it's like, "Wow, I understand that if that [study] didn't happen, I wouldn't be here," and [yet] I'm not trying to create the next me yet. I want this to be my time. So, I do like the vault idea or something like that. Maybe, I don't know, if the research is lagged by [only] three years or something like that." 39:13 Athlete

This athlete accurately identified the tradeoff that is required for this solution. Where although an embargo may increase recruitment/Reach and would likely increase Adoption of the research by agents and players' associations, the Effectiveness of both the biobank and HPR would decrease as any restrictions on data and sample sharing would slow HPR discovery and ultimately the implementation of innovations into use. However, there are compromises that could be envisioned, such as allowing research to progress but enforcing embargoes for sharing data and samples with those affiliated with the sports industry (e.g., teams or others in positions of power over athletes' playtime). Another possibility would be to embargo publications or sharing of individual-level data or results until a sufficient number of years has passed. For embargoes to be utilized, additional research and community engagement would be necessary to determine what compromises are both acceptable to recipients and yet still feasible for researchers.

Other Implementation Strategies identified in these interviews were to collect the minimum data necessary, implement high-level encryption, utilize contract language to include strict penalties for abuse, and/or to only share data and results in aggregate. One researcher who works with transgender athletes promoted data aggregation (Implementation Strategy) as a good tool due to ease of re-identification in a small group, but acknowledged that in communities with very small numbers, like transgender athletes, it may still not be enough to prevent re-

identification (Reach). This participant explained that with their research, they require a separate consent to allow researchers to share potentially identifiable data publicly.

> "It's certainly true if we're testing transgender athletes, that many of them are worried about public perceptions. And it's certainly true that, if their data are presented at conferences, or however. Or in papers, or other manner, it's often fairly easy to figure out who the transgender athlete is. […] Well, one of the first things we tell the athletes up front is, that there's two tracks. We anonymize everything and try to be sensitive, but certainly we understand that, if we're presenting data on an elite trans athlete in a specific sport, then there's a pretty good chance that they'll be able to be identified. So upfront we say, "Is this something that you're okay with? We will anonymize, we will do what we can to protect your privacy, but these data are important. We would like to talk about them. If we do talk about your data, you may well be identified." And if they say they're okay with that, then we proceed. If they aren't okay with that, then we only present their data in a group format." 27:37-8 Non-Athlete Role

This Implementation Strategy of allowing athletes to control how their data is shared via consent aligns well with concerns raised in the Control of Usage section. This type of solution is expected to protect the most vulnerable athletes from re-identification and potential discrimination; therefore, it would likely improve the study's recruitment of diverse participants. Therefore, the Reach implementation outcome should improve, and an improvement in generalizability would likely improve the Effectiveness outcome for both HPR and the biobank. Similarly, it is expected that non-athlete support staff will also be more comfortable with this research if access to samples and data can be controlled. Therefore, this implementation strategy is expected to improve the Adoption implementation outcome as well. Furthermore, if combined with some form of embargo that allows the release of individual data at a predetermined future time or restricted usage to researchers not embedded in the sports industry, reproducibility could still be preserved.

Ultimately, maximizing strict confidentiality will likely require researchers to employ a combination of multiple options such as sharing the minimum data necessary, employing strong clauses in contracts, utilizing data encryption in storage and sharing, restricting access to controversial parties, and data aggregation. On-going stakeholder engagement is recommended to ensure decisions are appropriate for all parties involved; see the Engagement Section in the White Paper Results for additional information. Additional discussions about the findings reported herein can be found in the Confidentiality and Discrimination Section of the White Paper Results.

Return of Benefit

Contextual Factors for Return of Benefit

As described above, athletes' willingness to participate in research was frequently conditional (see General Findings Section for examples). Participants universally expected some type of benefits related to athletes' performance abilities to be provided by HPR (see the Return of Results Section of the White Paper Results for detailed discussion). Participants frequently described research participation as being transactional, where athletes would trade their secrets to success, time, and energy for some direct benefit, such as learning how to improve their performance and/or gain a competitive edge (also see the Return of Results Section of the White Paper Results for detailed discussion). This athlete clearly illustrates the calculation that many athletes discussed with regards to their willingness to participate (Reach):

> "…as like a current professional athlete, I would say I'm not going to go out of my way and spend time and effort for something that isn't going to directly, I guess benefit me, just because of the schedule and everything like that and how busy you are." 22:39 Athlete

These expectations for return of direct benefit were determined to be primarily rooted in the Characteristics of the Research Interventions, Recipients, and the Organizations. The Recipients' Characteristics, specifically their desire for direct benefits from research participation, often interact with the Characteristics of both Interventions (HPR and the biobank) as, traditionally, research participation does not include a promise of direct benefits.[223-226]

The Characteristics of the Research Interventions were presented as hypotheticals due to these interviews being conducted during the exploratory phase of the research. Interviewees were provided the opportunity to discuss barriers and facilitators for research participation. For HPR, the description of the types of research being conducted was based on the researchers' priorities. The description did not explicitly say whether participants would or would not receive any feedback or results, but the phrasing may have implied that results would be provided. Nonetheless, participants not associated with the research team universally discussed how research participation could directly benefit athletes, with most indicating research would result in acquisition of knowledge that could improve performance. Amongst researchers, research participation was described as a way for athletes to give back to the community, but there was one researcher who discussed how the research needed to be more directly impactful to people than a heavily Life Sciences approach.

The biobank, on the other hand, explicitly stated, and was often reinforced in follow-up questions, that this research does not traditionally provide any feedback, including results or information related to any future research). The biobank described future research as being unspecified by primarily related to human performance, but the future research may include DNA testing and other scientific techniques not yet developed. Again, many participants discussed the potential value of receiving information back from secondary research. In many

cases, it was unclear whether participants wished to have their own results or study-level results. This athlete clearly illustrates the ambiguity in whether the desired information would be individual- or study-level. This participant went on to explain that they imagined some studies could be too scientific in nature for non-scientists to understand.

> "I think it depends on what research is being done [in the biobank]. If it were other performance-based research or health-based, maybe it would be good to be able to get that information back. But then there's this level of stuff that probably the general population wouldn't even understand some of this information that's coming back. I think there's a line." 45:24 Athlete

This qualification restricting what type of information was returned was not common amongst athletes, and most athletes reported an interest in knowing what was being done with their samples and data and what the results were (again ambiguously). The next section discusses in more detail the athletes' reported interest in the uses and sharing of their samples and data.

In discussions of the biobank, participants were sometimes provided two scenarios for how they may be enrolled. The first would be part of HPR where they may receive individual feedback and all samples and data collected from that study would be shared to the biobank for future research. The second scenario was being recruited prior to a clinical procedure, such as a surgery, and they would be asked to let the research team collect leftover samples from the procedure and to pull health information from their medical record. These two scenarios offered more nuance to discuss considerations of the amount of time and energy required for research participation versus a potential for receiving direct benefit from a research study. Participants often expressed more acceptability of biobank enrollment if the athletes received some direct benefit, such as HPR results, in return for research participation, as highlighted by this participant:

> "They [athletes] might be altruistic, but definitely there's motivation when there's information that's provided. As long as

> there's some information that's being able to be shared with the athletes that's helpful, "And by the way, there's going to be this bank," most guys I think would consider it as possibility." 35:46 Athlete

This quote also ties in the Recipient's Characteristic of wanting feedback and personal benefit as a form of compensation for their participation, even in the event that research participation only requires passive data sharing, and this quote highlights that altruism may not be enough of a motivational source for HPR and biobanking to successfully recruit aspiring and professional athletes.

Others reported that biobank participation without results may be more acceptable due to the lack of time and effort being asked of them. Again, this shows how the study design and Recipients' Characteristics, specifically the high value place on their time and energy, interact. Amongst these participants, several questioned whether the consent and/or consent process would adequately describe the potential risks that sharing their information and samples would include. This participant describes how the two scenarios related to the two types of people (Recipient's Characteristic) who would participate in the different options. They also directly address the potential issues with consent for a biobank prior to a procedure.

> "…there are two different buckets, there are two different target markets. One is just passive. This is a person who doesn't want to lift their finger and come in, isn't that engaged. You're presenting them with an option that they can kind of all right, I helped someone I saw. They don't even think about that now this is the bank. They don't read that part unless you're really hitting them in between the eyes. You're like, "You understand it's the bank, people can access this." Unless that's happening, which I doubt it is, I just think that's a different person versus the person that wants to go in and be a part of this and go through tests and get something out of it…" 26:70 Athlete and Non-Athlete Role

Recipient Characteristics were interspersed amongst the discussions of the interventions, but some Recipient Characteristics were facilitators to research participation. A common

characteristic was that athletes are curious by nature and thus would want as much information about their bodies and performance as possible (see the Athlete Characteristics Section of the White Paper Results for detailed discussion). This former professional athlete and now coach summarized this well:

> "I think athletes are always curious. They're curious about performance. They're curious about other athletes. Are they different? Are they the same? So, I think you would get fairly... You'd get good participation numbers." 15:1 Athlete and Non-Athlete Role

The context of Recipient Characteristics mentioned above was that for many participants there would be an expectation that research participation would return benefit in the form of receiving individual-level results. Similarly, aspiring and professional athletes are both too busy training and competing to take time away for something that does not provide them any direct benefits. However, many athletes also pointed to knowledge about their body and performance more broadly as a benefit.

> "I think athletes are generally curious about their body, that everyday they're evaluating their capabilities for that day, and they want to understand why they're getting better, or how they perform, or even gaining any sort of edge. So, I think if there's immediate feedback to them, I think some athletes want to pay it forward. But I think generally when you have a short career window, you need to maximize that. I think [if] there's some immediate feedback that whether it's vetted or not, they want to know about themselves and provide some context, they're usually interested." 26:13 Athlete and Non-Athlete Role

Several participants pointed to the ability to interact with research and top researchers as another potential benefit. This same participant discusses that potential benefit but how some direct benefit is still needed.

> "I would potentially do it to show up and meet 10 people that I don't know how they might help me, but I know they're really good, and it's people that I might not meet." 26:69 Athlete and Non-Athlete Role

This was similar to how another athlete described what HPR could look like for them to participate, but if they were not getting anything back, they would not be willing to participate. Again, this highlights the interaction between the Intervention's Characteristics and the Recipients' Characteristics.

> "So if somebody was like, "Hey, we have this new... We can do a more refined kind of correlation between power and your lactate curve", right? Like "We can get down to the watts?" I would have been like "Oh, that's cool. I would do that." And if they said like, "And we'll measure it over time or over the course of an entire season so you know when you're getting better or worse," I would've been like, "I will do that."
>
> But if somebody was just like, "Hey, we want to find a really fit person just to get a VO2 sample," I would've been like, "I'm not sitting on a trainer and going flat out for you on a Saturday," and I just wouldn't have done it." 34:31 Athlete

This last quote also points to a related to Recipient Characteristics included the need to spend what little extra time and energy they had outside of training and competing to participate in a research study (see Cost of Participation in Return of Results Section of the White Paper Results for detailed discussion).

How results are shared was also discussed in relation to the Recipient Characteristics and athletes' mental health. Athletes indicated that an unpleasant result, such as an increased risk of injury, could have a negative toll on their mental fortitude and decrease their ability to perform and win as described below (additional discussion in the Impact of the Research Section of the White Paper Results).

> [Discussing high risk injury result being given to athletes] "I think once you get into the mind negatively of an athlete, they can't compete. If you're not in that right mindset, you're not going to win. And I think that that's true of team and individual players." 38:23 Athlete

Furthermore, the competitive nature of athletes (Recipient Characteristic) combined with Organizational Characteristics for team sports where most participants feared that research results could be used against athletes to devalue them as players (both in monetary value and playtime; see the Confidentiality and Discrimination Section of the White Paper Results and Strict Confidentiality above for more discussion). Therefore, participants generally agreed that any research results should be provided directly to the athletes, and athletes would decide if they wished to share them with their support personnel and/or teams (see Return of Results Section of the White Paper Results for detailed discussion). This former athlete and current physician's recommendation that athletes control the sharing of their results was similar to the feedback given by most participants.

> "I think again, probably the athlete should be the one, I think in control of the information." 30:57 Athlete and Non-Athlete Role

An agent described the Organizational Characteristics of teams and their physicians regularly measuring and evaluating athletes to determine if an athlete can play professionally. This participant connected these experiences with the athletes' distrust in doctors (Recipient Characteristic), which may be driven by these evaluations, to the research Interventions' Characteristics of asking athletes to voluntarily undergo similarly thorough evaluations to why athletes would need a direct benefit (Recipient Characteristic)

> "…a lot of athletes right now they're analyze and overanalyze right now. And when you sit there, and now you go to the combine with an old meat market. Where they're looking at you and they're going through analyzing everything going on. And people are picking and pulling at you at the combine, to see what's wrong and overanalyze with MRI scans and everything else. It's almost like it's being done from a standpoint of, what can we do to figure out making sure we make an investment in you, that we're not making a mistake. Whereas, it's kind of tough because athletes have a natural distrust of doctors when it comes to it, they want to compete. They want to be out there on the field. So, you have to convert the whole mindset of, this is how it can help you, as

> opposed to, it being something that gets discovered," 32:43 Non-Athlete Role

Another concept that was commonly shared by Athletes was an idea that research results would be clinical-grade or would be immediately useful. The concept of therapeutic misconception about the purpose and results of research is common in biomedical and biobanking literature, and it is important for researchers to take into account when discussing personal research results, both during the consent process and return of results.[224,226-228]

Organizational Characteristics also impacted why participants in general reported that most athletes would not participate in research that did not provide direct benefits. One recurring theme was that athletes are frequently measured and evaluated by teams and trainers, which takes a mental toll on them (see Assessments in the Impact of the Research Section of the White Paper Results for detailed discussion). Therefore, athletes would likely not be motivated to endure more testing without gaining some personal benefit. This athlete described how often athletes do not have access to the results of these assessments and expresses their desire to have access to this information:

> "…the teams do their own risk evaluation per player, and they don't share that information with the player. So it's not like as a player, I know how much health I need to improve on or whatever, in their eyes. So all the coaches, the trainers, everyone has this information, but it's not something that's available to the players. So, it would be interesting if there was a way to get the players this information." 22:25 Athlete

Other participants noted that in addition to being frequently measured and evaluated, many athletes do get 'real time' feedback from their teams and trainers. This participant contrasts the much slower research process to demonstrate why athletes may not be motivated to participate in research.

> "The challenge with kind of traditional research is you're going to tell that player 24 months later. You know what I mean? Seriously,

> you have to take the data in, you've got to run it, somebody's got to pack it, and you got to get it out. It's such a forensic thing, but today's athlete and today's clubs and organizations, all of them are treating N of One. All of them are doing some form of evaluation through monitoring or evaluation daily. A lot more organizations are being set up to intervene as part of their kind of standard operating procedures. That's happening relatively fast." 42:28 Non-Athlete Role

This quote also points to the researchers' Organizational Characteristic where scientific results are slow to develop, as well as the Organizational Characteristics of teams' and personal trainers' who are conducting regular assessments and providing athletes with precision training and immediate feedback.

The contextual factors described above point to the perceived importance of receiving results for athletes to participate in HPR and/or biobanking. Similarly, they highlight important considerations for researchers who are considering how to implement returning research results to participants, such as the need for clear communication if findings are not validated and the need to empower athletes to choose who their results should be shared with. This need for athletes to control the sharing of their research results is also related to the next section, Control of Usage.

Implementation Strategies for Return of Benefit

Based on the overwhelming importance of the need for direct benefit to be returned to athletes, researchers should consider returning both individual- and study-level results to participants whenever possible. In addition to providing direct benefits, this adaptation to the research interventions would improve communication and transparency regarding the research itself, which are important factors related to the next section, Control of Usage. One participant familiar with the researchers' priorities suggested that the study that seeks to unify all priorities,

including bench research and in-depth digital analysis of movement, is more holistic and implied that it would be more pragmatic and useful (Implementation Strategy).

> "…the majority of those [research priorities], until you get to your phase of moonshot [/priority] four really, again, gets into very, very, very thin slices what might be happening at the cellular level or the muscular skeletal level. I think the one missing thing right now, but you do grab it in moonshot four, is both the psychological drivers, if we will, both in just pure cognitive function, kind of the motivational drivers of why people do what they do, which is very definable…" 42:6 Non-Athlete Role

As such, one implementation strategy would be to have one all-encompassing HPR study that could maximize participants' ability to obtain meaningful feedback and results while also maximizing participation for the biobank and bench research that is unlikely to yield many individual-results that can be practically integrated into one's performance. The anticipated impact of this adaptation on the study's Reach implementation outcome is likely to depend on the quality of the results provided to the participants. However, it is expected that this adaptation, regardless of changing the study's reach, would improve the HPR and Biobanks' Effectiveness implementation outcome. First, this adaptation would collect universal and standardized data and samples that would improve the quality and quantity of data for all studies, including future research via the biobank. Second, even if the overall reach of the study does not increase, it is expected that this adaptation would increase the reach of studies by Life Sciences researchers who are less likely to provide results as an incentive to participation.

Other adaptations (Implementation Strategies) include returning both individual- and study-level results to participants in language that is accessible to participants (i.e., not merely returning journal articles; see the Engagement Section of the White Paper Results for detailed discussion). From the feedback received, it would be ideal if the biobank also returned as many results as possible, both individual- and study-level. However, as one physician scientist pointed

out, the improvement in recruitment (Reach) needs to be weighed against the feasibility for the biobank as this would require a large amount of labor and cost (Implementation and Maintenance).

> "I think in a mass setting, if the participants want to be notified of a publication or journalized research results, I mean, obviously that's easy to do. On a one-to-one basis, as you allude to, that's not been standard of care. I guess I think that would put more onus on the researchers and make tracking of potentially thousands or tens of thousands of samples in patients who all want their results possible, but that may help enrollment. I don't see it as a critical portion of the process unless you want to throw the kitchen sink at it and try and improve enrollment as much as possible." 10:13 Non-Athlete Role

~

> "… from an enrollment standpoint, it [returning results] would be nice, what's in it for them [the participants], but boy, that is a huge logistical challenge, in my experience, and can lead to a lot of problems. I'm not sure it's worth overcoming the current standard community practice of just banking it and not having access to their information, right? I mean, part of it depends on how much money you've got in your funding mechanism, right? So, if you've got 10 FTEs to deal with, 10,000 phone calls about what does this mean, then maybe it's worthwhile. But if you're running a barebone ship, I'm not sure that the risk of all that data and releasing it individually to patients is worth it." 10:31 Non-Athlete Role

As highlighted in this quote, the literal costs required to accommodate returning individual results for all secondary research may not be feasible either for the Implementation itself or for the Maintenance of this research after the initial Alliance work is completed. Therefore, researchers must balance the Reach outcome with logistical issues that could hinder other outcomes, such as in this case Implementation and Maintenance.

Again, a compromise is possible for the biobank as one participant noted that even having early-access to study results could be perceived as a direct benefit (Implementation Strategy).

> "If there's any elements in there they could be shared and could be given back to the athlete or it could be a, listen, we're going to study this, but you're going to get the first look, a preview of what the results are as a participant in this study. I think those kind of things potentially could help." 7:16 Non-Athlete Role

Healthcare providers determined that a multidisciplinary team would be best for returning individual-level results, and mental health providers emphasized the need to support athletes in this process by framing findings in a body-positive manner (see the Impact of the Research Section Return of Results Section of the White Paper Results for detailed discussion). These recommendations would increase research implementation costs, but they are also expected to improve the study's Reach and Maintenance as athletes were said to share experiences and trust other athletes (summarized in the Engagement Section of the White Paper Results).

Furthermore, dissemination of results to individuals is also a strategy to increase awareness of the research, which if results are determined to be meaningful and useful will likely improve recruitment efforts. Similarly, as non-athlete stakeholders, such as teams and agents, learn about the research through athletes sharing research results perceived to be useful and/or beneficial, they would be more likely to buy-into the research and by increasing the Adoption outcome, one will further increase the Reach outcome. This action is also expected to improve the HPR study's Maintenance implementation outcome as the word spreading between trusted advisors is a highly sustainable recruitment tool. Furthermore, if the biobank implements some form of return of results, this is anticipated to improve the biobank's Maintenance implementation outcome as athletes will be less likely to withdraw from the research if they are receiving on-going benefits. As with the previous scenarios, improved Reach is also anticipated to improve the generalizability and thus the efficacy of studies, so it is likely that this change will also improve the Effectiveness implementation outcome for both HPR and the biobank. The

relationship of this implementation strategy on the implementation outcomes can be seen in Figure 3.1.

It is expected that there will be a variety of permutations for how results may be returned to participants, and it may be possible to identify quality control tests in the biobank that would provide meaningful results for athletes. As discussed in the Athlete Characteristics and Health Disparities sections of the White Paper Results, other benefits are possible beyond individual study results, such as access to resources within the research group (e.g., nutritional counselling or remote video analysis feedback). Researchers are highly encouraged to consider performance-based benefits in addition to or even in lieu of financial compensation.

Control of Usage

Similar to the discussion in Return of Benefit where athletes' were identified as the ones who should control who, if anyone, receives their individual research results, there were both expections and aspirations expressed in many of the interviews that athletes' should be able to control their own samples and data (discussed in-depth in the Consent and Engagement sections of the White Paper Results). This sentiment often stemmed from a shift in culture within the sports industry towards empowering athletes (see Athlete Characteristics of the White Paper Results for detailed discussion), and this new culture brought with it an implied expectation that any research being conducted with athletes would also be inclusive of an empowered athlete.

As such, the Recipients' Characteristics combined with the External Environment (culture shift in the sports industry) to push back on the two research Interventions' Characteristics and the Organizational Characteristic of the researchers. Similar to the Return of Benefits, the Recipients' Characteristics of wanting to control their samples and data and

Interventions' Characteristics of traditionally giving all control of samples and data to researchers come into conflict.

Contextual Factors for Control of Usage

The Recipient Characteristics of empowered athletes who seek to control their own bodies was a major component for this theme. One athlete spoke about the experience of being an athlete where one feels like others control their bodies.

> "...you're used to your body not necessarily being yours, but in the control of somebody else's per se. A lot of times it feels that way, you do as you're told, and you're just controlling your body." 22:24 Athlete

Similarly, many athletes reported being regularly subjected to testing and measurement, as mentioned in the Strict Confidence section above and discussed in-depth in the Assessments part of the Impact of the Research Section in the White Paper Results. It was thus notable that athletes sought out the right to control any additional testing and evaluations by emphasizing the importance of providing athletes' with information, support, and time to make informed decisions (see the the Consent and Engagement of the White Paper Results for detailed discussions). This was best summarized by a mental health professional when they described how researchers need to support athletes who are deciding whether to participate in HPR.

> "I think one thing that is very beneficial, especially with working with the professional athlete space is getting an idea of who their legal team is because the legal team pretty much is the entity that provides the breadth and the depth of advice with the lens of protections of the athlete. […] It also requires for anyone who's involved with the athlete, with regards to their own medical team, who they're very familiar with. I think it's extremely important so that they can actually make an informed choice and an informed decision based off of some of the things that they get from those individuals who are part of that support or ancillary team." 17:15

This quote also highlights how support for the research by Non-Athlete Role stakeholders is critical and how the Adoption implementation outcome relates directly to the Reach implementation outcome.

Many suggested that consent be used as a means of empowering athletes to have more control over both what types of samples and data they share and how these samples and data are used in the future. Similarly, the consent was recommended to be very specific advising why these samples and this information was necessary to answer certain research questions.

The External Environment included a culture shift in the sports industry as well as legal rulings that supportathlete empowerment and provides the backdrop for what researchers need to consider when implementing their two research interventions. This culture shift was described as driving atheles' autonomy, sense of ownership, and higher levels of empowerment (Recipient Characteristics; see the Athlete Charateristics and Engagement of the White Paper Results for detailed discussions). Therefore, this interaction between the External Environment and Recipient Characteristics was reflected in the frequent suggestions that the researchers should give athletes more choices and control, usually via the consent process (Implementation Strategy; see the Consent Section of the White Paper Results for detailed discussion). Below, a team's trainer describes one way (Implememtation Strategy) that the research team could adapt to align with this culture shift (External Environment) to further empower athletes to control their samples and data (Recipient Charaterisitics):

> "Does that mean they're going to give up a hair sample? They're going to give up a skin sample? They're going to give up a muscle sample...Clearly [explain] what they're going to be giving up and why they're going to be giving this up. I think as long as that's very clearly outlined, and then honestly, I feel like giving them options. Maybe they want to give two of the three, instead of saying, "We need all of these things." Give them a way that they can still participate, but it may not necessarily be 100% of what you want,

> but it gives you 80% which is still hopefully worthwhile." 9:13 Non-Athlete Role

Both themes that the research should be hypothesis-driven and athletes should be given as many choices and options as possible were recurrent themes and are discussed in greater detail in the Confidentiality and Discrimination, Consent, and Engagement sections of the White Paper Results. Others brought up the sense of ownership athletes have that may be stronger than in the general public (see the Athlete Characteristics and Commercialization of the White Paper Results for detailed discussion), which is likely the result of the culture shift and legal expansion of Name, Image, Likeness (NIL) licensing rights to college athletes in the External Environment affecting the Recipients' Characteristics.

This brings us to the External Environment's contextual factors that may be driving agency in the professional athletes. Some participants described a shift in the sports industry that was recognizing athletes more holistically. One mental health provider described this phenomenon in terms of privacy and allowing athletes to be more than just their physical performance.

> "…there's also this huge swing in the pendulum of movement in terms of athletes privacy. And being able to not just solely be seen as an athlete, but seen as a whole person. I think there's some contention that might be present. Yeah. Just the increased awareness of self-advocacy and recognizing that the athlete identity is not the only identity at play has been a part of an organization, I would say in terms of the athlete culture really leaning heavily into the why behind things and being able to engage in things that are more reciprocal than unilaterally. So that has been an increased trend in a direction of hope, just to care for athletes." 17:10 Non-Athlete Role

Another aspect of this culture shift within the sports industry was empowering athletes. This took several forms, but many of the discussions either alluded to or named the Name, Image, Likeness (NIL) licensing rights as a driver for athletes' sense of ownership over their

bodies and data. This physician describes how the concept of ownership may grow stronger as athletes progress through their careers.

> "…probably even the collegiate, elite and professional realms, when you're talking about physically taking samples, then there's a lot of this, like not, intellectual property is not the right word, but like proprietary-... ownership. Ownership of the stuff, and I think a lot of that factors in of whether or not athletes want to participate into those kind of research.: 8:2 Non-Athlete Role

Similarly, this concept was extended to athletes' having a right to future commercial profits from innovations created using their samples and data (see the Commercialization Section of the White Paper Results for detailed discussion). Overall, the participants described improvements in athletes' autonomy and connected these with how the research should be designed and conducted.

The Interventions' Characteristics contextual factors also impacted participants' desire for more control to be given to the research participants. First, the biobank's Intervention Characteristic of traditionally being a black-box that generated unknowable research from the participants' perspective was a major component of the conversations. This complete lack of transparency and control were frequently reported to be problematic with respect to professional athletes. This former athlete who works with a team to develop their internal human performance program succinctly describes the recurring sentiment about athletes' desire to control their information.

> "I think they would be highly skeptical. The lack of control is not something most professional athletes would welcome, especially when it comes to sensitive health and genetic data. So that would be a hard sell." 26:27 Athlete and Non-Athlete Role

Similarly, the black-box approach has been deemed unacceptable in the European Union where the General Data Protection Regulation (GDPR) requires consent for all uses of data instead of using broad consent for future research as is currently the practice in the US, although

there are many efforts to change this practice.[137,229-231] A lawyer who specializes in data privacy also pointed out how the black-box approach may create conflicts with international collaborations.

> "It's the open-ended, forward-looking nature of it that I have the most problem with, and I feel like, especially if this is going to be an international effort, I can almost guarantee unless there's an aspect of the law that I haven't read yet, you're going to start running into trouble with stuff like that in the EU. Because they're going to say every time you share it outward again, there needs to be a new consent, and I think that's probably the way to go, frankly." 29:27 Non-Athlete Role

On the other hand, HPR's Intervention Characteristic of asking athletes to donate their time, undergo invasive procedures and/or comprehensive evaluations (such as MRIs), and share their performance secrets and health information, which both relate directly to their incomes, also contributed to the sentiment for athletes' to have control over what is given by them. There was a wide range of responses amongst athletes regarding their comfort with research with some being willing to do whatever is asked if HPR can help people, some expressing a qualified willingness where certain perceived senstative data would need special permission, to those who were unwilling to risk participation due to the uncertainty of the risks. One example of an athlete being comfortable in general but placing restrictions on a sensative topic was from this athlete who felt they should be asked for permission for each different use of genetic information.

> "In general, I wouldn't be super concerned about necessarily knowing that my data and information was used, but I don't know how I feel about my DNA just being used in a study that I don't necessarily know about, or that I don't know what's being used for at all. That seems kind of sketchy. […] I would still want to be able to have the option to opt out or in." 46:17 Athlete

Again, there is an interaction between the Recipients' Characteristics and the Interventions' Characteristics in the athletes' desires to control the future uses of some or all of their samples and data. Examples of sensative data included mental health, genetic, hormone

replacement therapies and surgical proceedures within the trans community, and menstrual data (see the Confidentiality and Discrimination and Disparities of the White Paper Results for detailed discussion).

Finally, the Organizational Characteristics of the researchers themselves was a factor as they are traditionally the locus of control when it comes to making decisions for research practices and policies. As alluded to in the return of benefits section above, researchers do not have much on-going accountability to participants and typically do not engage with them when it comes to future research. Similarly, this research group (Organizational Characteristic of the researchers) was described as wrestling internally between focusing solely on Life Sciences studies, or bench research that rarely engages with participants after consent, and more interventional or Clinical studies that are more focused on changes within an individual. This internal struggle highlights the importance of determining what the researchers choose to measure for assessing HPR's Effectiveness outcome. One researcher described this tension as being either human- or science-centered.

> "I keep trying to bring it [HPR] back to humans and what do we see in terms of disease? What do we see in terms of health outcomes? What do we see in terms of longevity in sport? More so than the cellular level, because if we're not applying this to our actual players and our patients, then it's all just play to me. It's all just fun science." 20:50 Non-Athlete Role

Implementation Strategies for Control of Usage

The research consent form was brought up by many participants as a way to facilitate giving athletes more control over both what samples and data are collected and how they may be used and shared in the future (Implementation Strategy). This strategy took various forms from having a menu of options at the time of enrollment of what samples and data could be collected, to identifying acceptable secondary uses at the time of enrollment, to being able to consent for

each future use. This last option, when combined with the Implementation Strategy above to enroll athletes in one over-arching study, could both maximize benefits and allow athletes to control what types of samples and data they wished to share (both External Environment and Recipient Characteristics). These strategies combined are expected to improve recruitment and likely generalizability thus improving the Reach implementation outcome. Non-athlete support infrastructure is expected to be more likely to buy-in to research that is more likely to benefit their athletes and allows athletes to have more control over what information is being shared. Thus, improving the Adoption implementation outcome.

However, there is a strong possibility that very few athletes will elect to undergo invasive sampling, such as blood draws or muscle biopsies, or share more sensitive health information, such as allowing genetic testing. For example, this athlete was very supportive of the research in their interview, but their fear of needles was a non-starter for research participation.

> "I mean, I understand why they're doing it, but let's say if I did decide to hypothetically join in on this research, I probably wouldn't do it just because I'm scared of needles and stuff. So I probably wouldn't do it." 23:29

As previously described in the desire for benefits, the use of evaluations to determine team sport athletes' ability to play professionally (32:43) is likely a contributing factor to why athletes would want to limit the information provided. This drive within athletes to minimize the amount of information collected about themselves was reinforced by this team trainer with regards to athletes' willingness to undergo an MRI (Recipient Characteristic), which is reinforced by their agents (Organizational Characteristic), is again related to the team sports' use of health information to devalue athletes (Organizational Characteristic). All of these factors are likely to be barriers to HPR research participation if the research requires in-depth assessments, may return negative performance-related information to an athlete's medical record, and/or

shares such information with teams (Intervention Characteristics) unless athletes have control over how this information is used (Recipient Characteristic).

> "So many of them due to the industry and due agents and protecting their clients will tend to only want to necessarily like get an MRI or an x-ray if it's really necessary because it becomes part of their medical record. And once that medical record gets created and they're a free agent and now they can sign with either and now other doctors are looking at those records and say, "Oh my gosh, this guy's got a horrible looking elbow. He's got a terrible looking low back which is he's not going to last for very long."" 9:46 Non-Athlete Role

Therefore, despite the improvements to recruitment (Reach Outcome) and support staff buy-in (Adoption outcome), the Effectiveness outcomes for both HPR and the biobank are anticipated to go down. Researchers could mandate key samples and data be shared, but this compromise is similar to traditional research consent. Another option would be to incentivize more invasive procedures by providing more direct benefits, such as analyses that are not commercially available.

Another suggestion (Implementation Strategy) was to use consent to improve transparency and communication by allowing participants to either opt-in or opt-out of future research studies. This athlete describes their desire to control their genetic information (Recipient Characteristic), considered by many to be sensitive data, and that a notification system (Implementation Strategy) would not be sufficient.

> "I don't know how I feel about my DNA just being used in a study that I don't necessarily know about, or that I don't know what's being used for at all. That seems kind of sketchy.
>
> [Asked if being notified of use would alleviate their concern]
>
> I think that would help, but I think I would still want to be able to have the option to opt out or in." 46:37 Athlete

This ability to opt-in or -out to each study is also referred to as study-specific, dynamic consent, and the opt-in version is what is required by the GDPR.[230] However, an opt-out model would allow research to proceed in generally the same manner as is currently done in the US. This option would also allow those who have no concerns about future uses to do nothing to remain active. Whereas those athletes who want more control over future uses would be able to monitor and approve every request. Given that many athletes reported having robust support networks, researchers should consider ways to allow athletes to delegate these decisions to family members, agents, or other trusted advisors. Furthermore, this option could ease athletes' concerns about who is accessing their samples and data, and the players can control if they wish to allow teams to use their information. One downside to dynamic consent is fatigue, which is also avoided with the opt-out model. Finally, having athletes consent to future research would also create a system that facilitates sample tracking and return of results, both study- and individual-level.

Offering dynamic consent, another option for empowering athletes, is expected to improve recruitment and likely generalizability, thus improving the study's Reach implementation outcome. Similarly, non-athlete support infrastructure is again expected to be more likely to buy-in to research that allows athletes to have more control over what information is being shared. Thus, improving the Adoption implementation outcome. However, researchers who request samples may be less likely to buy-in as a consent process would delay sample requests, could result in fewer samples being received if athletes opt-out of their studies, and due to increased time and effort to interact with participants. This latter concern could be alleviated with automation. Although, dynamic consent is hypothesized to improve recruitment (Reach) and hopefully generalizability (Effectiveness), the researchers would need to decide if a decrease

in samples and secondary research, which are also measures of Effectiveness, are worth the improvements in the study's Reach. As the generalizability improves the quality of HPR results that are disseminated, the ability to conduct research with more diverse samples and data is expected to incentivize many researchers who were initially avoidant of the biobank's new process to return. The on-going communication is likely to improve the Maintenance implementation outcome as regular communication and improved transparency are expected to build trust and may discourage participants from withdrawing from the biobank. Furthermore, if results are returned as well, the on-going benefits will likely offset any malcontent frequent consent requests may induce. Lastly, this adaptation will require front-end investment by the researchers to set up a system that obtains consents and can return results at-scale. Therefore, these changes could be captured as part of the Implementation outcome and weighed against any measurable changes in the other outcomes of interest. The relationship of this implementation strategy on the implementation outcomes can be seen in Figure 4.

3.2.3 White Paper Results

Note: The study findings reported herein supplement the Implementation Results. These results are included in the White Paper without quotations, and the quotations herein provide evidence to the White Paper Results. To minimize duplication of results in this document, the generalizable manuscript(s) will incorporate the results below with the Implementation Results.

General Findings

Overall, all stakeholders reported a high interest in HPR and most reported biobanking to be acceptable. However, most athletes' reported being willing to consider participating in both forms of research was conditional on such things as anonymity and/or getting some benefit from participation. Perceived benefits of research participation included curiosity, ability to learn more

about their performance, potential to improve their performance, gaining access to otherwise unavailable or unaffordable technologies and experts, and general concepts of altruism. Below is a selection of quotes that speak to this finding:

> "It sounds like it could be something that would be super helpful. Not only the results of it, but even participation in it because it's a process. I think as athletes we always want to be learning more about our own bodies and how they respond to different stimulus, and being a part of that I think even just helps you learn more about yourself along the process. So, to me, that would be something exciting." 46:32 Athlete

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> "They [professional athletes] will be interested in doing this, in my view, if they think it has some immediate benefit to them. I don't mean financial benefit. I mean that results will somehow improve the safety, life of the players. Some might be moved by broader objectives to just help the world, that volunteer. But you're probably talking about a smaller slice of the athletes being motivated to do that." 12:28 Non-Athlete Role

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> "I'm somebody who likes to know as much as I can about this, I'm really curious about it...I think athletes in general are all pretty much curious by their body because in a way, you're used to your body not necessarily being yours, but in the control of somebody else's per se. A lot of times it feels that way, you do as you're told, and you're just controlling your body. Well, if you start giving athletes the power of really understanding their body and really knowing how their body functions, then maybe, I don't know. I don't think there's any negative to this at all. Me personally." 22:24 Athlete

However, several participants thought that participation without conditions was possible, but this was a minority of the participants.

> "I think athletes are always curious. They're curious about performance. They're curious about other athletes. Are they different? Are they the same? So, I think you would get fairly... You'd get good participation numbers… I think by and large I would participate, and I think most athletes would… They may not have anything that will come back, but they'll be curious about the

whole process and find it interesting. So, I think you'll probably have fairly good participation." 15:21 Athlete and Non-Athlete Role

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"I don't have a problem with it because I have the trust in scientists and doctors, and I wouldn't think that they would want to do something to harm us. I think that they would want to help the next generation. So, if I'm able to donate time, or samples, or knowledge, or experiences to them to better shape the next generation to make my sport rugby or any other sport or life better for the next people, I'll I'll [sic] do that any day of the week." 28:18 Athlete

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"I don't really have an opinion about it, because like I said, it's the benefit for the study. It's not for me. It's not for someone specific or whatever. So it's just benefiting the research for the future. So I'm okay with that. I feel like in today's society, we do things for the benefit of ourselves. We're very selfish. And so sometimes I think about, I want to do it because I want to, I don't know, make someone else's life better in some way in the future because they have more information about sports and medicine and things like that. So, I guess I'm giving back, I would say." 23:36 Athlete

Athlete Characteristics

Available Protections and Support

Support infrastructure, financial resources, and legal protections, varied widely amongst athletes. Support infrastructure and financial resources varied greatly by type of sport, gender, and level of career.

Individual Sports/Team Sports

This team owner describes the variability in how team sports and individual sports secure their salaries and the 'what's at stake' calculation that athletes make when considering HPR participation.

> "But I think it depends on the sport, right? If, if you're a college athlete who you think is going to be a lottery pick for the NBA, you don't want to muck up whatever's working right now, and you seem on your way to a payday. If you're for instance a track athlete who you will sign a sponsorship contract, but you won't be signing a deal that then guarantees, regardless of performance, over a certain number of years, it's going to be every single meet. And what you do at that meet is going to affect how much you win and earnings and all the other things. Same with golf where there's not the guaranteed money. So each tournament you have to perform in order to earn a certain dollar amount. And then you get the sponsors that are more of that safety net. I think the sport would probably affect whether or not you'd most care about it [HPR participation] versus 'everything's working, I don't want to mess with it,' or offer potential barriers or frictions to the people paying me kind of vibes." 31:42 Non-Athlete Role

Other Distinctions within Professional Sports

A more complex observation noted by several participants was the potential impact team funding and salaries may have on research participation. These participants discussed how lower-grossing sports, such as women's and emerging (e.g., rugby or lacrosse in the US) sports, may be more interested in HPR due in part to their sports having fewer resources for internal HPR. Similarly, as a result of these sports having lower salaries, often due to structural and

systemic barriers, athletes from these sports were speculated to possibly have more interest in research participation due to having less financial risks for participation. One strength observed by several participants was that these lower-grossing sports were perceived to have more supportive teams and cultures where suboptimal performance metrics were treated less punitively and training accommodations were more likely to be implemented.

> "It's not just because they're women [WNBA and Women's National Soccer Team]. There's something to that, but I think, and maybe it's because they have to fight more for, I think the smaller leagues like now you have a professional lacrosse league that I would see that group as being more engaged. It's important to them to be able to thrive and succeed and it's like anything, right? […] But I do think the smaller leagues and maybe it's as simple as there's not that as much at stake and just in terms of protecting longevity of their league and making sure that players stay as healthy as they can, I just think it gets easier with those smaller sports. The big four are probably the hardest." 18:21 Non-Athlete Role

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> "Very little of that [high-tech research from national team] trickled down to the league stuff. It was only at the highest, highest level at that point. I'd imagine some of the teams have some more of that incorporated in now in the NWSL." 30:37 Athlete

~

> "We work with the lacrosse team who are professional and earn salaries and everything, but they're not necessarily making your millions of dollars a year. They're going to be a little bit different than your baseball guy who's making $30 million a year, what have you." 6:11 Non-Athlete Role

Perceptions of risks related to research participation varied by level of success (see Life Course below) and type of sport.

> "…but rugby is very different than a lot of other sports where the values of it, the culture, the respect with those players, with the opposition, with the coaching and the rugby family. So I think it sounds a little bit of a safer space that I hear about. Because I can always speak on professional rugby, but I've good friends that have

> played professional basketball, professional football and baseball. It's a whole different mindset that's for sure." 28:15 Athlete
>
> ~
>
> "*I mean, I think that you would hope that, over time, the information would be used to, particularly for younger athletes, get a better understanding of what they should, and shouldn't be doing as youngsters, how to develop your body in the most efficient, proper manner, injury free, that type thing. I don't think the risk really comes until you start getting into a business setting, where information can be used to try to devalue you in a negotiation." 25:17 Non-Athlete Role*

Access to highly skilled, dynamic agents and robust players' associations were often limited to athletes with higher grossing, team sports. This labor lawyer describes the differences in union representation.

> "It's just that the team sports in this country are the most organized and have the most money, so they're easiest to access and deal with […] But again, they're [tennis players are] more loosely associated […] It just isn't as easy to get a body, a group to represent them." 12:10 Non-Athlete Role

This soccer player described the role money played in the type of agent an athlete is likely to have.

> "I also didn't have a big time agent and wasn't a super high paid player or anything." 30:69 Athlete and Non-Athlete Role

Similarly, team athletes still striving for success frequently reported their agents at this stage were strictly contractual intermediaries between themselves and teams.

> "Well, he's [my agent is] basically just there to present contracts to me. He doesn't really serve any other purpose, besides the median between me and the club." 45:25 Athlete
>
> ~
>
> [Asked if would consult with agent about research participation] "Probably not. No. I don't think I would've when I was playing. But I also didn't have a big time agent and wasn't a super high paid

> player or anything. So maybe that stuff didn't occur to me as much." 30:69 Athlete

These representatives were frequently identified as trusted stakeholders who could advise athletes about the potential professional risks and benefits of research participation. They were also identified as strong advocates for protections that are athlete centered, as demonstrated by these quotes.

> "If you have, usually agents or anyone with a lawyer background, their adversarial mind has been literally honed to always look for the worst possible scenario, because that's what you need to do for contracts and other things." 31:47 Non-Athlete Role

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> "So, I think that [focus on a continuum of care] very quickly feeds from the players and to the PA [players' association(s)]. [They are] Very closely connected to the players, is likely their families and then their agency. And then, honestly, like it's just the way it is." 11:29 Non-Athlete Role

Most participants reported athletes' high levels of trust in their support staff, including training staff; this was strongest during college and in emerging sports.

> "I think when you're in college is the time you have people helping you all the time that know what they're doing and can give you exercise and watch you. And I think that's really useful." 36:16 Athlete

This athlete later by expanded on the difference between college and professional support infrastructure:

> "I would probably have my trainer from UNIVERSITY because when you're a professional, I don't know how it is for other teams, when you're here you sign contracts for multiple years usually. And for us [professionally] it's year by year, so those people are changing constantly. […] I would trust them [the college trainer] more than a revolving type of person." 36:6 Athlete

Athletes in individual sports indicated that support services, such as coaching, trainers, and agents, were paid for out-of-pocket, resulting in many having very small support circles and

less financial resources. This tennis player describes how expensive it can be as an individual sports player.

> "…Even in the top hundreds, it's not guaranteed that you're legitimately making a lot of money because you're paying all your expenses. […] So it is really hard to actually make a living." 43:22 Athlete

Another athlete from an emerging sport who was also an Olympian contrasted the holistic and multidisciplinary resources available to Olympic athletes compared to the resources offered by their professional team. This athlete also described how the Olympic team could be used as a protective asset in their professional careers.

> "There's definitely more when you get to that Olympic level […] When I was younger, I was with the national team and so when I would leave the national team and go to another team that didn't have these resources, we still had the other resources available in the off season of the national team […] I've had to get national team coaches involved and say, "This is what we do. You cannot change." We've had to go up a higher level to make sure that I'm not doing things that could potentially hurt my body." 45:30 Athlete

Athletes who were still striving for ultimate professional achievement and those in individual sports frequently reported being more likely to participate in research in order to gain access to resources (both human and technological) that they otherwise could not afford, often assuming this access would provide them with a competitive advantage. Similarly, athletes from disadvantaged backgrounds were also anticipated to be more likely to participate in HPR for personal benefit.

> "So people would definitely be looking to use this [research] as an advantage as well, for sure. Being able to regenerate faster, but then you're looking at, okay, so you're coming through the ranks and not every athlete has a ton of money to begin with to be able to pay for that stuff. It's also how accessible would it be, because then you're dealing with, okay, all the top players are going to be able to stay at the top because of all this good technology. So then there could be an even greater divide within sports." 43:9 Athlete

~

> "Poor high school kid or poor college student, how much do I have to pay to get this information? And if there's no cost to you, then yeah, probably [they would participate in HPR]." 35:31 Athlete

Legal protections were also described as varying across sports and skill levels. For example, it was discussed how professional teams with robust players' associations often have enhanced genetic discrimination protections in their contracts. Whereas the NCAA does not have any additional protections beyond federal and state laws. The risks associated with breaches of confidentiality go beyond the risks of re-identification to the general public for participating in research as athletes' employment and/or careers are based on their abilities to physically perform. Many participants discussed scenarios related to concerns that research data may be used against athletes by athletic organizations (including colleges).

> "We can't have human samples being used for discriminatory analysis. So, in the pros, there's a genetic non-discrimination act, which you're probably familiar with. The NCAA has not, to my knowledge, gone that far. […] ...if you are getting into genetic testing and storage of genetic information with markers that may potentially lead to an increased risk of injury or increased risk of health issues, control of that information is going to be critical" 10:7 Non-Athlete Role

Several participants discussed the variability in protections for athletes across their sports career with regards to what kind of information is made publicly available by organization type. Specifically, institutional requirements to share data publicly vary across skill level. For example, most public universities make share student athletes' "de-identified" information performance data publicly available through the Family Educational Rights and Privacy Act, which is not protected by HIPAA. When all publicly available data is taken in aggregate, the risk for re-identification for college athletes could be as high or higher riser than professional athletes and thus bringing risks for future discrimination.

> "Interestingly at the college level, you have FERPA [Family Educational Rights and Privacy Act] and you have HIPAA [Health Insurance Portability and Accountability Act]. So, you have your medical information, and you have your educational record. In the pro level, you're just dealing with HIPAA…" 41:13 Non-Athlete

Continues by discussing how these regulations can fail to protect confidentiality of college athletes.

> "So, let's talk about [college] soccer. So, we have on any given week, we have soccer games. We only have two goalies per team. We only have typically one goalie to play a game. And let's say one of those goalies has a shoulder injury on the first week of October, and they're the only goal[ee] in the DIVISION that have a shoulder injury in the first week of October. So, […] we have a standard electronic medical record system, and […] all of those data points are then aggregated and de-identified, so name and other specifics, in order to allow for robust research by our folks to help increase our understanding and treatment and care and prevention of injury and other health considerations, medical considerations. But the fact of the matter is […] if I Google "shoulder," "[DIVISION]" "shoulder injury," there will be a [NEWSPAPER] article about the [UNIVERSITY] goalie who left the game with a dislocated shoulder. So, you can connect those dots." 41:16 Non-Athlete Role

Often during the interviews, a hypothetical injury risk score was used as an example of a research result to discuss if any limitations were necessary in sharing that result. Professional athletes in independent sports, however, reported having less concerns about data sharing or others having access to their research results as they primarily controlled their careers.

> "I don't really know what other factors there would be [to consider about research participation] besides it takes time…
>
> [Example of injury risk score being given to a team]
>
> Yeah. I didn't even think about that, to be honest. Well, because it's individual, it's not on a contract. My brain would never go there. It's just the risk ... because it's all your own risk in tennis." 43:23 Athlete

~

> “If my opponent knew about it, I think that they would go in being like, "Oh, sweet. If I do this, or make her move a certain way, will she get injured?" […] If you kept it anonymous and published it in research, I don't think it would be a big deal.” 38:24 Athlete

A few athletes discussed scenarios where sponsors received the hypothetical risk score and these athletes reported that sponsors typically only cared about whether they were winning. Nonetheless, several athletes identified how research results could impact sponsorships.

> “I would want everybody to know [about my high injury risk score]. Everybody who is important to me and in terms of my athletic career, I would want my coach and my husband, and I would want them to know…I suppose like you wouldn't want sponsors and stuff to know that kind of information…” [Participant explained that their sponsorships are not endorsement deals but more related to discounts on products for brand promoting activities.]. “So, for me, it's not really that big of a deal, and if you told those people [my sponsors] what my injury score was, they'd be like, "What the fuck? Why do I care?"” 46:14 Athlete

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> “Probably depends on the sponsor. I think they're more concerned with, well, whatever you're doing off the court. ‘Okay. But are you getting the wins?’ 'Cause if you're getting the wins and speaking to the public, then we're [sponsors are] getting more money. I think if they knew, "Oh, this person has a high injury risk." They'd maybe be like, "Hmm, do we really want to give them this?" Or, "We'll give you a trial." I think it may raise some red flags.” 38:33 Athlete

Athletes’ resources also impacted their access to healthcare. One participant noted that having more financial resources allowed athletes access to more trusted healthcare providers.

> “Yeah, so it's interesting because the dynamic with professional athletes depending on their monetary resources and other resources that are available to them, they might have access to a team position or medical care providers who are affiliated with different entities as it relates to their sport. But again, depending on their level of resources, they actually access those services outside of the structure and outside of the system, based off of the fact that they have the level of trust with individuals that they might not necessarily have with individuals who are close to proximity with a

> perceived interest or agenda in getting them to return to competition as quickly as possible." 17:16 Non-Athlete Role

A number of participants indicated that athletes typically do not have their own primary care physician, even after they retire.

> "It's always the team's [doctor]. Yeah. It's always the team's. You can get your own if you need." 36:44 Athlete

~

> "Typically, players don't have their own physicians. Even after they retire, they often rely on the medical staff and the relationships they had, which is why we have an issue of not having primary care physicians. It's an area we focus on for the transitioning player." 21:74 Non-Athlete Role

~

> "But right now, the support staff run a small healthcare system for the players, for their significant other, for their kids, and their extended family, and deal." 42:26 Non-Athlete Role

One athlete, physician spoke about how the lack of a primary care doctor as an athlete likely caused a delay in their hypertension diagnosis (Record 30).

> "I probably didn't have a primary care doctor when I was playing soccer. But actually, they [the team doctors] were starting to pick up a little bit of borderline hypertension for me on some of my testing. […] since then I have developed hypertension, as a young [pregnant woman], I had preeclampsia […] And now I have chronic hypertension […]
>
> I think had I had a primary care doctor at that point, it probably would've been good information for me to discuss with somebody. And it would've probably been on my radar more […] Because I think sometimes what happens is, you get all this data collected about you. You get analyzed, whatever, but that wasn't really a marker that was related to sports performance at that point, it was just something about my own health. It wasn't really something that was that concerning or addressed. And it wasn't like, it was a major abnormality. I had a little bit of borderline stuff at that point in time. But yeah, I think a lot of times, the team doctor is it's [sic] all very sports related, but there's other healthcare too that is important as well." 30:15 Athlete and Non-Athlete Role

Agents and players' association representatives and most professional athletes spoke at length about the conflict of interest inherent in the team physician position. Although there were exceptions noted, agents and players' association representatives and most professional athletes from high-grossing team sports did not view team physicians as trusted advisors. Some discussed the frequency of team physicians who testify against athletes as a major source of this distrust.

> "…There are some of those same team doctors, the ones that are at the combines [recruitment and pre-signing evaluation events], that are picking and pulling, doing x-rays and scans to see exactly [an athlete's health status]. But they're reporting that information to protect the teams from what's going on. So, if that's the case, they can probably do a heck of a job protecting the teams again, if the athletes are being used." Non-Athlete Role 32:35

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> "A good team physician one, who's not testifying against the player in a worker's company, yes, definitely a stakeholder. But they are employees of the team and I worry sometimes they forget their Hippocratic oath and their duty to the patient." 21:74 Non-Athlete Role

Multiple participants spoke about how athletes should always seek a second opinion when they are injured. This second opinion was reported to be dramatically more conservative than the team physician's recommendations.

> "I didn't necessarily have my own personal physician or anything, but the team does have their own doctors, and they have a whole bunch of them. But the one thing that you are always recommended to do and advised to do by the players' union and your agent and other players, is to go to your own doctor to review all your information. If you get injured, send your MRIs to a different doctor that's not affiliated with the team, just because doctors who are paid by the team, are paid by the team…
>
> Researcher: Did you find any major discrepancies between what the team doctor said and what another doctor said?
>
> Participant: Oh yeah, always. It's never even close. Team physicians are always going to say you can come back on the field

> in two weeks, your personal doctor's always going to say it's going to take two months.
>
> Yeah, you're just wasting money sitting on the bench. It sucks. But I mean, unfortunately, a lot of ethical lines get crossed when the body is the one that's the performance. It's like, it's the product is a human body, well, where's the ethical line in there?" 22:49 Athlete

Several retired athletes spoke about experiences they deemed medical malpractice during their careers, but they believed that the team physicians were better now due to players' associations' advocacy.

> "I got cut over the eye and it was a pretty deep cut and went into the training room and the doctor came in and I could smell him when he leaned over me that he'd been drinking. And he put three stitches above my eye, and I went back out in the ice and it just kept bleeding. And so, I came back in, and he goes "Well, we will butterfly it up and you'll be fine."
>
> And I got home that night, and it was still leaking, and so I went to the local hospital [HOSPITAL'S NAME][…] the emergency room doctor took one look at it, he goes, "Whoever did this should be sued for medical malpractice." And I said, "It's the team physician for the [TEAM'S NAME]." And he said, "Oh, I know that guy. He's the drinking buddy for [OWNER'S NAME] who owned the team." And so, he put 21 stitches in." 19:27 Athlete and Non-Athlete Role

This hockey player continues later by expanding on what they perceived the role of the team doctors when they played.

> "The team ownership management did not want doctors or trainers that were going to stop players from playing. So, it was in the ownership and management's best interest to get the players back on the ice as quickly as possible." 19:30 Athlete and Non-Athlete Role

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> "I've already had a changing impact because of the medical malpractice that I was the victim of. And so hopefully things are better today from the mistakes that were made with, by, and on me." 5:9 Athlete

Team physicians, on the other hand, rarely discussed this conflict, and instead, they viewed their positions being as focused solely on the athletes' health and well-being. Below are how some of the team doctors spoke about their roles in players' health:

> "I do think that the team part of keeping our athletes healthy is something that I'm very involved with." 20:30 Non-Athlete Role

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> "I also work with the TEAM as one of their team physicians. And so, we're always looking for injury prevention and mitigation tools, not only treatment, but injury prevention tools for the professionals and colleges alike." 10:3 Non-Athlete

Life Course

Participants were asked about how HPR and biobanking may be perceived differently at various stages of athletic development, from childhood through college, as professionals at their peak and at retirement.

Most athletes felt HPR with children would not be advised, pointing usually to the research creating unhealthy expectations and risked "taking the fun out of the game." Managing parents' expectations about if and how the research would assist their child in becoming a professional athlete was a major theme in the appropriateness of recruiting child athletes.

> "I think it's a bit strange if the parents do it [enroll in HPR] for the kid, because it just ultimately puts a bit of pressure on it. So I mean, if it's like, "Oh my child." You hear it all the time. "My child's in a 90 percentile and a hundred percentile of this. This is a football player, or this is going to be a basketball player. This is Olympian." And I mean, you hear that and you just like, "Oh, I just feel so bad for the child because their parents are expecting that."
>
> And they [the parents] forget the reason why. And it's mostly parents that never reach those heights of professionalism of everything else and they live through their child, I notice that. But […] man, be careful for what you wish for, because at the end of the day you just want them [your children] to be healthy and happy and enjoy sports so they can get the most physical excellence, you can get socialization, you get team, you get all this positive things

> coming from recreational sports, but there's an ugly side of sports as well." 28:27 Athlete

~

> "I feel like just one thing I worry about with youth sports is, it's gotten so far from youth sports, it's so much about not having fun anymore. […] I don't know if you would ever plan on doing this type of stuff on youth athletes, but I don't know about that. […] I guess maximizing performance as a youth athlete, but it's just, I don't know, sports are supposed to be fun. And I feel like when you get too much into that, when kids are too young, it takes away from the joy of sport.
>
> […]I could see some parents getting hold of some of this stuff and going crazy. Just, that's one thing I worry about at the youth level, is how it [HPR] would trickle down and what that means for youth sports and parents trying to get their kids into whatever and maximize everything." 30:62 Athlete and Non-Athlete Role

Managing parents' expectations about if and how the research would assist their child in becoming a professional athlete was a major theme in the appropriateness of recruiting child athletes. This tennis player describes how they see parents treating their children in youth sports.

> "I could see where maybe parents would test when the kids are super young and then picking sports based off of that. But that I feel like then you're going into a little bit of psycho parent, where the parents want the kids to be a professional athlete and they're trying to find the best sport. And that's where you would see parents forcing the kids into the sport, which I would not agree with." 43:3 Athlete

This participant continued by explaining the lengths some parents go to make their child a professional athlete.

> "…there are so many parents that want their kids to be pro athletes so badly and they will do anything that they can get. The amount of kids that I've played against that were given HGH [Human Growth Hormone]…" 43:12 Athlete

This participant finished this discussion by describing parents' possible motives for their actions.

> "…then you get kids coming up and parents pushing the kids to be the best and they either don't care or they just see the magic solution could get to the top and be raking in millions. So they see the kids as a cash cow basically. And there's a lot of those parents in the tennis world." 43:39 Athlete

Although some participants thought that for exceptionally skilled children, it may be beneficial to both their performance and science to understand how they developed over time.

> "You've seen such a market increase in performance...So in cycling, there's this big resurgence of youth talent. The winner of the Tour de France is 22 years old now. Before, they used to say... When you were my age... I retired at 31. When you get to be in your thirties, you're in your prime. And I retired, I was the fittest I ever was, but I was nothing compared to the kids coming up…And the reason being, or the speculated reason why, and I believe it, is that the training these kids did when they were... 14 was the training I was doing when I was 25. So they got a 12 year head start. And so I think the more understanding that comes out about human performance is going to make human performance better, so that's how I feel about it." 34:7 Athlete

~

> "We happened to have a kid on our team this year, he's going to be a sophomore. He played varsity as a freshman. I didn't step on the field with considerable playing time until my junior year. Here's a kid who has multiple scholarship offers before he is a sophomore in high school. Knowing that [HPR] information, if I were in those shoes, maybe I would want to push this a little bit more, I'd be more motivated." 35:59 Athlete

~

> "Oh, I think it would be fascinating to [have my child participate in HPR], especially the idea of there being an athlete gene, knowing that from a young age. Is that something you would really want to know at that young of an age?" 46:28 Athlete

Most participants indicated that late-career athletes would be most willing to participate in research due to these athletes already achieving their career goals. Late-career athletes and retired athletes were described as being more focused on their future health and addressing any negative impacts playing professional sports may have caused. Most participants advised that

recruitment of college athletes would likely be easier than professional athlete recruitment, mainly due to accessibility. This variability across athletes' career spectrums was best described by the following quote that is representative of a numerous participants' feedback related to the various life stages of aspiring and professional athletes.

> "I think college athletes are much more open [to research participation], and it's interesting because it's an interesting time in college sports with them being able to pursue all kinds of licensing agreements and things that I think there's much more empowerment for college athletes to make decisions for themselves about everything. Their likeness, their image [NIL] and their health data too. So it might be actually a very good time to be able to get college athletes to participate.
>
> And as for the pros, I really think the hardest time is when they're in the peak window of their career, the peak earning power because the hardest thing is going to be to get them to participate in anything where they have some worry that whatever they do will circle back and ultimately impact their next contract or that's what it is bottom line is that.
>
> Now, a lot of them, when they get to the tail end of their career or a lot of these athletes participate afterwards, they're concerned about their health. When they're young and they're going into it, they tend to feel more invincible. And I don't think they think about those things as much, so they don't care if they don't participate. I think when they're getting toward the twilight of their career, they're much more interested and engaged…" 18:18

This shift in focus for retired athletes was emphasized by one participant due to their lack of access to health insurance, lack of having primary care providers, and difficulty obtaining appropriate medical care due to long-term effects of professional competition not being well studied. This human performance researcher for a professional team recommended that the research team build trust with current athletes by first helping retired athletes.

> "I do think the untapped space, which is still really the untapped, is the former player…Just like the VA, no one wants to take care of it [retired athletes' health]. So, if you wanted to, right now, go after and support a space […] they're a bunch of busted up retired, former players who dedicated their life, their body to the game,

> that I don't know are getting cared for. And, I don't think anyone's going to fight you over.
>
> […] I think that we still don't really know how to care for those individuals [retired athletes]. And so, on a VA-ish similar-ish model, there's less resources for former major league athletes [than] for professional athletes than any group. And, I don't think there would be a lot of resistance there. And, I do think all the PAs [players' associations] wanted to take care of it, they just don't know how.
>
> […] I think that would be a relatively efficient landing spot [for HPR]. Then, you get the PAs involved. "Oh, this is really neat. How do we now vertically integrate to some of our current numbers?" That would just be an interesting way to strategize to connect to the model." 11:25 Non-Athlete Role

Most participants described aspiring and professional athletes being short-sighted, secretive, and hyper-focused on obtaining greatness in their sport. Most participants spoke to the short career windows for professional athletes that lead athletes to being hyper-focused on attaining this goal.

> "Professional athletes are not going to want to do anything that could be viewed as having an adverse effect on... again, it comes back to in large part, and I totally respect and understand this, their careers tend to be very short. They're very protective of that, not just time, but that career. I think there's always going to be some skepticism. 'Oh, we got to gather your biomedical information and we'll store it away and it'll help future generations.' There's always going to be some inbuilt skepticism in terms of, 'Are you just taking it to replace me or to use it against me?' That's just, that happens I think in professional sports." 7:15 Non-Athlete Role

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> "*I think, again, that is wired into us that if we find something amazing, we want to help and express to other people how to do this. But at the same time, it could be selfish, call it whatever you want. But a lot of the athletes have been working 20 plus years to where they're like, "No. I finally found my one thing that sets me apart."" 39:2 Athlete*

Many non-athlete stakeholders identified college as being a much easier time to recruit athletes due frequently to the fact that they do not have players' associations and rarely have agents at that time. Minor League Baseball players were also described similarly.

> "Minor leaguers will participate. It's just different…Well, one, they're not in the major league players union, so the players union has historically cautioned their guys in participating in things like this." 26:20 Athlete and Non-Athlete Role

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> "Again, at the minor league level there is no union, so we can basically, I would say force, but we can definitely strongly encourage our players to do any of these things." 7:44 Non-Athlete Role

Athletes, on the other hand, were mixed about research participation during college. For some, they recalled being already overextended by training, school, and college life in general and therefore would not be interested in committing more time to participate in a research study.

> "To be honest, during college, I probably wouldn't have done it or even just out of sheer laziness. […] While I was in college, I graduated in three years […] from the honor's college. If you had come to me and been like, "Hey, do you want to be involved in this research study?" After all this schooling and stuff, I'd probably be like, "Nah, I'm good right now." After all the all-nighters I pulled finishing my research and doing all that, I wouldn't have wanted to be anywhere near a research study at that point is what I'm getting at personally." 43:30-31 Athlete

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> "No, I'd probably feel a little bit differently. Because you're not in it yet and it's not your job yet. And I guess, you're less one track minded in college. Yeah. But still, I mean, I'd be pretty busy in college too." 33:37 Athlete

Others reported that if HPR participation was easy and part of their team's activities, they likely would not have declined the opportunity.

> “And then when you get college... The ease of it, it would just need to be super easy. And time is always the issue, I feel. But in college I think I would be pretty open to it.” 33:18 Athlete

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> “So we participated in a lot of studies at UNIVERSITY, where they would come to the football building and do different testing and stuff like that. And so that was never a problem, just because it was just part of being the university and stuff.” 22:72 Athlete

One participant who described themselves as a very private person who would not want to share their health information unless they received direct benefits indicated that they likely would not have considered the risks of participation the same way when they were younger. This participant advised that they likely would have participated in research when they were younger because the invitation alone would have made them feel important.

> “…when I was younger, I would've done it [participated in research]. And I think I would've done it solely because I think when you're a young athlete... you tend to be really full of yourself. And so, it kind of goes back to the thing I was saying before about how you could show off. And maybe I would've thought of it like, "Oh, people want my blood sample. I'm so cool."" 34:54 Athlete

Confidentiality and Discrimination

Confidentiality

Several participants discussed that athletes are likely at a higher risk for re-identification due to the large amounts of health information publicly available. Re-identification was considered likely with as few as three demographic and/or phenotypic characteristics. For outliers and more famous athletes, some participants suggested that as few as two demographic details would be needed to identify an individual athlete.

> "I could look at someone's pitch metrics and TrackMan data and just from knowing all that stuff on record, if you showed someone to me that's really good, I could say like, "Oh, that's probably Josh Hader, because his release height is really low, and his extension is really high. And he's throwing 97 at this spin rate." I would be able to do that. And so with the body, yeah, I think someone would be able to do that too." 33:46 Athlete and Non-Athlete Role

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> "There's also considerations for privacy and engagement. Also, you want to make sure that people actually participate in your research, so you want to be able to ensure standards for privacy. But there's always risk, especially whenever you're a high-profile individual who is well known. Nobody's going to know whenever I have a shoulder injury, but when Joe Burrow has the shoulder injury, […] you're going to know who it is. That also goes to who should have access to that data and understanding the parameters and the processes of ensuring that it's only access for certain purposes and by people who are beholden to privacy standards and all the like. But yeah, there's no perfect solution." 41:17 Non-Athlete Role

Sports gambling and celebrity status of elite athletes were reported to be reasons accessing and re-identifying athletes' research data as it would be more valuable, particularly compared to health data from general public.

> "So there's going to be a lot of concern about the athletes, about the keeping control over their health information and keeping it confidential [...]The big issue the players have there, the unions, is consent and confidentiality, and not having the data

> commercialized. This whole concern that people are going to sell this data for gambling, and so there are issues that surround that." 12:26 Non-Athlete Role

Another major component for team sports athletes' was that their medical records are also a part of their employee files, so the teams and leagues have historically had no boundaries on what health information they are entitled to.

> "They [Teams] keep a file that has all of your medical records, but it's your [employee] file. And it's private. Now, they always ask for it. When you're a free agent, the first question I get from a team is, do you mind sending me the medical records? Well, if I say, "Yes, I mind," in 99% of the cases, I've just scratched my player off of the list to be considered because the implication is you've got something to hide." 25:43 Non-Athlete Role

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> "That's supposed to be the understanding [that medical records are protected by HIPPA], but of course there's been too many scenarios, situations where teams have known information on a player prior to him getting there [medical records]. Information that's been leaked. […] These trainers, these doctors, they all know each other, and inevitably, it's no different than anything else. General managers, they all speak, "Well, this guy here, we had to let him go because he had the knee injury that we're worried about." So that's disclosing information without saying it. So, so much information gets communicated, that there really is no sense or real privacy. And I've told my players over and over again, "Do not think that there's real privacy." Even though you're supposed to have it, the expectation is that it's really not there. I've seen too many instances where guys are going in for workouts and teams already know exactly what to look for, when there is no way they should have known or could have known…" 32:2 Non-Athlete Role

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> "I think that the hard part, and it's a legal analysis and there's not really a resolution of this, is the distinction between employment records and protected health information. And if you asked an NFL or an NBA team, they would say everything in the EMR [electronic medical record] is employment records and thereby, not subject to certain protections. We [the players' associations] agree not to fight about that with the league and put the protections in

> place. And so, they acknowledge that they may be wrong, but they serve their position, and we just agree to put the protections in place." 21:14 Non-Athlete Role

Celebrity status was also suspected to increase the risk that the research staff and/or external organizations may be more motivated to re-identify and/or share participant information.

> "I do think there's probably a higher likelihood that their [famous athletes] data gets leaked or observations about them gets shared, or at least that's the perceived notion." 26:69 Athlete

Several participants discussed how athletes are generally desensitized to having their health information shared publicly by the time they were professionals. The potential impact of this desensitization was described both as being a facilitator to research participation and a possible blind-spot for athletes to not fully consider how sharing samples and health information for research could negatively impact them.

> "Guys in the NFL, it's normal for guys to publicly know that they've gotten COVID and they're going to be off for five days. They've had a knee injury, they've had a shoulder injury, they had a concussion, all that is kind of put out into the world for gambling purposes. So, it's publicly available. So, most guys become a little bit desensitized to that information being out there, maybe more so than someone off the street who's like, "No, that's between me and my doctor, and I won't say anything." Everyone of your potential employers in the NFL know[s] that you were out for two weeks or four weeks because of whatever injury it was. So, guys are a little bit more desensitized to that information being shared." 35:24 Athlete

The level of concern about data leaking varied by the type of data shared. The athletes' mental health and genetic data were frequently discussed as being more sensitive than other physical performance data (discussed in greater detail in the Consent Section). Menstrual data, although less commonly discussed, were also identified as sensitive data as several of these interviews occurred after the Dobbs decision (discussed further in the Disparities Section).

Most participants who discussed types of information generally said that video data was not risky as athletes were frequently recorded and video data was widely available in the public domain. However, several participants also noted that the availability of video data in the public domain would make re-identification of "de-identified" video data much easier. Several participants also observed that releasing low risk but easily identifiable data sources, such as video data, along with high-risk data or samples, such as genetic information, would be troubling. This quote represents these two concepts that were discussed by multiple participants.

> "I think for many athletes at the professional level and increasingly the college level, they're used to having a sensor put on or they're used to testing, they're used to being videoed, used to tech being a part of their normal workout regimen. That to them would perhaps have less privacy implications. I agree all of this information needs to be kept safely. People would be less worried about a video of them exercising getting out versus their genetic code would hit the wall […]
>
> It would be problematic to have video, which really cannot be…anonymized [shared] with genetic and information and demographic information. The demographic and genetic material can be anonymized fairly easily. If you're videoing people doing various things, you'd have to separate that out. There's facial recognition. A lot of athletes are photographed very, very widely. It would be almost impossible to guarantee privacy if you had video with demographics, with genetic material..." 6:40 Non-Athlete Role

Most stakeholders reported that confidentiality risks were tolerable as long as the research data was stored and shared "anonymously." Generally, stakeholders defined "anonymous" as the participant's identity not being able to be linked to their research data or samples.

> "It's not like you're linked to it. It's completely anonymous. Your name and stuff aren't associated with it anymore." 43:26 Athlete

Precision health research, however, requires researchers to collect detailed data about individuals' characteristics for discovery purposes. This researcher describes some of the issues related to confidentiality, but they also indicate that with the right protections in place the benefits to society and understudied subgroups will outweigh the risks.

> "I think there's certainly a question of data anonymity and being able to protect the health information. So obviously as an Alliance, we want to make sure that we're doing that in a safe way where we're not selling this information to companies, but in terms of getting more information, studying the elite level athletes so […] starting with the elite level and then trying to see what we learn there and then having that have a trickledown effect, I think can have a really big impact since women have been not studied nearly as much as they should be." 20:45 Non-Athlete Role

Discrimination

Many participants identified various potentials for discrimination against athletes if research data or results were shared beyond the athlete. Several athletes in this study reported concerns that if colleges, teams, or the general public were able to identify them in research results, they may face negative consequences. Many participants discussed scenarios related to concerns that research data may be used against athletes by athletic organizations (including colleges). Scenarios included reductions in play and training time at all levels, potential loss of scholarship opportunities, loss of future health insurance coverage, and the possibility of negative impacts on draft rankings, contract negotiations, and employment. This quote addresses the concern and distrust of both aspiring and professional athletes about sharing health information and describes how athletes' health has been used to unethically devalue them.

> "I just really think it comes back to everybody's always trying to make the most money that they can. Everybody's always worried that someone's going to come in and give reasons why they shouldn't [play]. And so, I guess the college athletes have as much to worry about because if someone were to come in and say, "Hey, we've learned that this, this and this factor mean you only have three years on average to make it. And so we're not going to pay

> you for a five-year deal when we know that the average expectancy is three." I can see why they'd be concerned, but I think it's in more of a generic way than specific.
>
> Yeah, it's hard because on the one hand, I don't think a lot of it is justified. On the other hand, I see it all the time [...] This year, for example, the NFL draft. You often see it where information comes out last minute about a player or their health [...] all of a sudden, somebody who was valued very highly starts to slip because somebody lets it be known that they saw something on the medical exam that made them nervous. So, their club has taken them off the board. Well, sometimes they lie. Sometimes they say that they're taking off the board, but they just want their draft stock to fall so that they're not worth as much for the contract. And that's awful, but it happens. So, does that mean everybody operates in that way all the time? No, but that's how that gets built is people see that. […]. Some of these folks [college athletes] are really, they're counting on this pro experience to be the life-changing financial thing […] I think this cloud of suspicion of everyone's out to get me is a bit over the top, but that being said, you also see these things or you've seen front offices try and do things to basically get the better of a player, not have to pay as much as they might otherwise have had to." 18:41 Non-Athlete Role

Similarly, another participant describes how some information is not allowed to be used in determining eligibility for scholarships or team positions, but if that information were to be collected in a research setting protecting the athletes' information is vital to minimizing risks for discrimination. In this example, genetic information was identified as being so risky to collect that the research does not warrant the risk.

> "But certainly, that's standard of care where any genetic information just cannot be used in college for scholarship decisions, team-making decisions, anything. And it's obviously certainly not privy to coaches or athletic department staff at all. And so that's the risk, is that that information were to get out. And I know at UNIVERSITY, we have about multi-levels of control to make sure that doesn't happen. And in fact, we have not really done genetic testing on our student athletes at UNIVERSITY, so we've just avoided that." 10:7 Non-Athlete Role

Some participants also pointed out that in addition to employment risks, athletes more broadly are also beholden to the 'court of public opinion,' extending concerns about confidentiality beyond their physical performance.

> "…I'm not in the business of making myself a public figure and want to be loved and everything. But I could see how, potentially, some of that [research] information might make people insecure or something like that. Maybe people who are more in the public sphere later on in life, potentially, they are digging up a lot of stuff on a lot of people lately...it's just the world we live in today. All that information can and will be used against you in the court of public opinion." 44:21 Athlete

The risk for discrimination extends to if and how research studies return research results to participants, particularly for athletes in team sports. One participant, see quote below, who is employed by a professional team described a scenario where an athlete receives research results for future risk of injury and then signs with a team. In this scenario, if the athlete were to not disclose said research result and then have that injury for which there was a known risk, the participant speculated that the athlete may be denied insurance coverage for failure to disclose.

> "It could be a massive future risk. You guys could figure out that some muscle biopsy, whatever, leads to X, Y, or Z. And then, maybe because there's known information, maybe an organization goes back and sues a player because they had this and now they were at greater risk recurring ACL, and they owe them this back money." 11:21 Non-Athlete Role

However, there was no consensus as to whether research results, as opposed to medical diagnoses, would be included in athletes' duty to disclose health information to teams at signing. Other agents and players' association representatives questioned whether the disclosure of a research finding would be required. Several indicated that the ambiguity and uncertainty of research results may shield athletes from future discrimination by teams. These discussions focused on the burden assumed by teams through their in-depth physical examinations and athletes' burden to report being limited to existing hinderances to their ability to perform.

> "I mean, once a team makes a decision to spend a lot of money on your client, the next thing they're going to do is have your client see their medical professionals. They're going to do their own MRIs. They're going to do their own evaluations, physical evaluations. […]
>
> It's incumbent on the player to notify the trainer every time he's got something that needs to be worked on. It would just be very hard for a player to prove that a player was intentionally misrepresenting. And there's language in the contract that deals with misrepresentations or material omissions as it relates to the insurance that the player gets or that the team gets on the player. But it's such a hard thing to prove. It's really up to the team to do all that they can do to try to figure out where that player stands physically." 25:12 Non-Athlete Role

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> "It's [the contract requirement is] ambiguous that they [have] to report […] any injury, anything that may prevent you from being able to play, is how I remember the verbiage spewing out. So, if it's an injury that may limit, but doesn't prevent you from playing, beauty is in the eye to beholder. Most players are not going to report something that they think may hinder but doesn't prevent them from playing. And, it becomes more litigation later on, if it becomes an issue, about what should have been disclosed and what should not have been disclosed. But you got to remember on top of that, each team gives each player physical. So, the duty switches if [the player] goes through and pass your physical, if it was good enough for your physical, there was nothing wrong. Why should there be a duty for you to report it? So, it's a catch-22, so to speak." 32:2 Non-Athlete Role

This conflation of protected health information and employee information was at times accepted as necessary for business and equated to all employers conducting performance evaluations on employees.

> "…how do you balance what you term is information that is owed to the people who p*ay your salary, who draft you, who trade you, who do whatever, versus what is private. When your body is your job and when your body is your skillset and the thing for which you are being paid and the thing upon which rests billions of dollars, where is the line between what it is required to be shared versus what is private and HIPAA?" 31:9 Non-Athlete Role*

However, as previously described, the lack of separation of private health information from both the employer and the public was described. These perceived controversial actions were described as leading to a general mistrust by athletes and non-athletes in supportive roles (e.g., agents and players' associations) related to sharing their health information. Several participants expressed that conflation between medical records and employee files was merely a tool to devalue current performance in contract negotiations. Several participants reported witnessing protected health information being shared broadly, either with other teams or with the media, without athlete's permission. This concern that athletes' research information may be leaked was also extended to the research staff. This quote from an agent describing their experiences with athletes' health information being leaked inappropriately captures concerns expressed by multiple participants. They also warn that the research team will need to proactively protect against data leaks due to the frequency of these events in sports.

> "There's a lack of trust. And not trusting the NFL with how they do [health] information […] It's supposed to be protected by HIPAA. It hasn't been protected. […]
>
> The toughest part would be, how do you guys [the researchers] truly vet employees to know who's capable and not capable of doing it. Those people working there, they become the sources and the leaks. […]
>
> And so, their [the media's] sources are teams, officials, most of the time. I've done so many deals where I've had one of those reporters call me and tell me, "Hey, sources say you guys are close to getting a deal." Well, I'm the only person speaking on this side; the player doesn't even know. So, it tells me, that's where [the information is coming from]. If you understand, there is a lack of trust, it is because there are sources everywhere, that just want to be able to say they told somebody something or did it." 32:61 Non-Athlete Role

The potential sharing of research-related health information frequently brought up concerns that teams and/or leagues may access research data. Ultimately, participants associated

with team sports reported that they expected research information would ultimately be used against athletes in employment decisions and/or contract negotiations. These concerns of discrimination also extend to other elite athletes, especially amateurs/collegiate athletes who hoped to become professionals in the future.

> "I think anyone associated with an owner, or an owner, that would scare people. Because it's like, "Why is the owner here? Trying to get my information." And like, "All right, he is going to trade me because my blood work comes back bad."" 33:9 Athlete and Non-Athlete Role

These concerns that information may be used against participants were also noted in individual sports, although less common.

> "…you kind of get scouting reports […] but like different competitive teams or players competing against each other, the coaches are going to scout out your opponent and say like, okay, I see them, they're moving well this way but not that way. So, it's using it against them to be able to enhance their own player or yourself to be able to say, "Okay, well I know they don't like to do this or that." And so, any information out there is, I guess, "used against them" to be able to compete and beat them." 40:21 Athlete

Impact of the Research

Human Performance Research

Many aspects of the potential outcomes of this research were discussed, and most potential outcomes identified by participants related to an expectation that participating in HPR would improve a participant's performance. The Return of Results Section below discusses how most participants stated it was important for participants to receive a direct benefit from the research with many pointing to receiving individual study results as one form of benefit. However, multiple participants questioned the effectiveness of the research itself and discussed other potential impacts this research may have beyond individual performance benefits.

Issues related to the generalizability of the research were brought up by participants. Several participants questioned whether researching elite athletes would be generalizable to the public. This former professional athlete and now coach discusses how elite athletes are inherently different from not only the general public but also each other.

> "There's just no secrets. It's elite athletes are different than normal people and their bodies respond, they adapt very differently, and they're not the same either. One elite athlete compared to another elite athlete is very different…" 15:32 Athlete and Non-Athlete Role

These participants pointed to the effects that a lifetime of extreme training has on one's body as being a major confounder to translating findings from elite performers to that of a more sedentary population. This athlete questioned how much studying elite athletes could help others who are less active.

> "Having that [HPR] trickled down to the general population, I don't know if I see the connection. If the questions or if the information is being created around this specific class of people, because it's very different than the general population The amount

> of energy you're exerting, and the way that you're moving your body, and what you're asking of yourself physically and mentally every day, is different than someone who's not doing something with their body every day. I'm not sure I see the correlation, but I'm not saying that it's not possible to help. I'm sure that any type of information that's adding healthy habits to someone's life, is positive. Something that's helping me and that's created for me help, I don't know, my grandmother? I don't know. I don't know if that's possible. I think there are some things." Athlete 45:32

Others, however, expressed the expectation that studying elite health would be useful and generalizable.

> "But when it comes to human performance, I don't think... Everyone needs to know regardless of what sport you're playing or if you're not even playing sports, just your daily demand. It's not about being an all-star, it's about being the best you can be and not be hurting." 22:59 Athlete

While others questioned if the research would equitably represent historically underrepresented and unresearched groups, which is discussed further in Health Disparities Section below.

Several participants, particularly those familiar with the Alliance's mission, voiced concerns that this type of research may be very interesting for scientific exploration, but they questioned the usefulness of this science to improve health and performance. One researcher and physician feared that the Alliance may be straying too far from the human component and that imbalance risks resulting in work that is only meaningful to the scientific community.

> "What are the areas that should be focused on? So, I think the athletes are number one, the people that should be engaged in this. Medical folks in terms of what are the issues that they see the most often [in my role within the Alliance], I keep trying to bring it back to humans and what do we see in terms of disease? What do we see in terms of health outcomes? What do we see in terms of longevity in sport? More so than the cellular level because if we're not applying this to our actual players and our patients, then it's all just play to me. It's all just fun science." 20:50 Non-Athlete Role

However, another researcher and physician described how they compartmentalize this issue for themselves as these two roles have different goals. Using the example of genetic research, this participant describes how research that may not be immediately useful is necessary to eventually inform clinical care.

> "I'm a clinician and also a scientist or a clinician-scientist, but from my scientific side, if we're talking about genetic information, I'd love to sequence their whole genome and run genome-wide analysis on their polymorphisms and see if we get markers. […] So, I mean, that's the researcher side, and that's what we see being proposed all the time from the researchers who are not clinicians.
>
> On the clinician side, right, I don't need to sort through 20,000 pages of genetic data. I want to know clinically actionable items, and that's the role of researchers or scientists and clinician-scientists to sort that out […]But of course, if you pick up a risk for sudden cardiac death or something like that, that's going to be something where we may have to say, "Okay, maybe this athlete shouldn't be participating in sports for whatever reason." So, it just depends on the hat you're wearing." 10:8 Non-Athlete Role

Furthermore, multiple participants noted that the scientific process may take too long for any potential results to be meaningful for participants, the importance of which is discussed in the Return of Results Section below. This trainer describes how professional athletes are getting real-time feedback already and contrasts this with how long research usually takes to get conclusive findings.

> "The challenge with kind of traditional research is you're going to tell that player 24 months later. You know what I mean? Seriously, you have to take the data in, you've got to run it, somebody's got to [un]pack it, and you got to get it out. It's such a forensic thing, but today's athlete and today's clubs and organizations, all of them are treating N of One. All of them are doing some form of evaluation through monitoring or evaluation daily. A lot more organizations are being set up to intervene as part of their kind of standard operating procedures." 42:28 Non-Athlete Role

One athlete indicated that research interventions, such as regenerative therapy, would need to be at or near the threshold of clinical interventions for athletes to be willing to participate due to the fear of not being able to perform (Record 38).

> "I think if you're at a high level to where you can't risk any setbacks, that it would be hard to convince you to do it. Unless you had really sound research that was clinically proven. You had peer reviews and lots of stuff to compare it to. I don't think something new, they would jump on." 38:12 Athlete and Non-Athlete Role

Other participants discussed research participation in terms of whether it would violate the Anti-Doping rules, particularly when any substance would enter their bodies.

> "And I think as an athlete I would have a couple of concerns, like how much time is it going to require of me? How's it going to impact my training? And making sure that it's safe in terms of anti-doping and stuff like that." 46:10 Athlete

Another participant pointed to the Alliance's Multiscale Athlete moonshot as having the most promise of generating meaningful information for athletes because they felt it captured the psychological component as well as the cellular information. This participant also questions how useful the cellular information alone would be for athletes, and ultimately, they recommended that the more holistic research would be more useful for athletes to participate in.

> "In reviewing the overall moonshots, […] the majority of those, until you get to your phase of moonshot four really, again, gets into very, very, very thin slices what might be happening at the cellular level or the muscular skeletal level. I think the one missing thing right now, but you do grab it in moonshot four [the Multiscale Athlete], is both the psychological drivers, if we will, both in just pure cognitive function, kind of the motivational drivers of why people do what they do…
>
> […] I think it's also part of, so what? Now what? That's the greatest thing with the research and these very thin slivers and some of these are getting at it, right? If we're talking about soft tissue injury and regenerative medicine and all the different little

> pieces that are the [other] moonshots. That gets down to a cellular level. […] That's great at a cellular level, but it's also like, what is the readiness or the state of readiness?" 42:6 & 42:9 Non-Athlete Role

Overall, participants agreed that acceptability of the research was directly related to the potential utility of the research for improving human performance, with few valuing scientific discovery alone.

Similar to these questions of the potential generalizability and utility of the research, participants frequently spoke about the importance of aligning the research with a common goal. This participant summarized this by discussing the importance of everyone involved understanding how all of the data and samples that are being requested directly relate to a shared goal.

> "I guess you just have to ask the question as maybe individually, what's the common goal? What is the goal out of this? So you work backwards from there. It's like, "We want data to X, Y, Z." And it's like, "Okay, how are we going to get that?" "This is how we're going to get that. Is everybody on board to make this sport safer, to make this person or to create better athletes, or to figure those athletes out sooner." […]
>
> …start with the finish line and work backwards. And what I found in sport and in life is, if there's a common goal, everybody's willing to work towards that and they'll do their share. But if it's not the same common goal, you're going to be at tug and pulling, it's going to get a mess." 28:35 Athlete

This need for a shared goal was also a common theme from non-athlete stakeholders as being key to obtaining buy-in from their groups as well as the athletes themselves. For example, this researcher pointed out that the current stated goals of studying all human performance, striving to help everyone ultimately, and working with UNESCO are too many goals and results in the Alliance lacking a focused priority.

> "I think this gets to what are the goals of the Alliance? And even at our meeting […] so much was going on, and we weren't working in a unified way to answer a whole bunch of questions. So, I mean to say, "Oh, we're studying all of human performance, and we're going to fix the whole world, and we're going to work with the UNESCO. And it's too much." So, we, as an organization, have to decide what is our priority [is] and hone in and do it." 20:38 Non-Athlete Role

Similar to discussions about younger generations training better than older ones and the secretive nature of athletes, one participant described how these factors could combine to harm participants if their information helped their younger competitors take their jobs. This athlete discussed how athletes are motivated by altruism but also by self-preservation. This participant identified how altruism in competitive sports has an inherent duality. They reported being conflicted between wanting to 'pay it forward' and help future athletes while also needing to protect their own secrets to success. They acknowledged that athletes' data and samples would likely help up-and-coming athletes more than themselves, particularly if not receiving personal results in a timely manner (more discussion in the Return of Results Section). This participant identifies the tension between wanting to have the best players and wanting to be the best player and how that relates to research participation that is likely to be present in all professional sports.

> "[If] you took every single metric, every single data, every time I performed, and you took that and put it away, it would not affect me immediately. It might affect me, I could still probably go pro […] It could affect me there. I could make it for a year or two. Then all of a sudden, some guys are coming. […]
>
> It is a very protective [mindset], I guess, instinct of you want to watch out for yourself. As soon as you understand you have something valuable, then I need to use that to the max and see what I can get out of it." 39:24 Athlete

This athlete goes on to discuss the competing motivations they have about wanting to help improve performance while also wanting to protect their job.

> "It is a weird complex of I've gotten to this point and now I'm in self-preservation mode, and to where I'm trying to give back to the game now." 39:13 Athlete

Furthermore, this same participant shows how an athlete's protective nature evolves over the course of their career, but the risks are the same throughout their career. This participant also discusses how college athletes may be more likely to participate, but it may be due to their lack of understanding of their potential and the risks related to sharing their secrets.

> "…in college they are a little bit more ignorant. There's more things going on. You're excited about being away from home. You're excited about having a little bit more freedom than you're used to. Sports is important, but maybe you don't realize you're at the top of your game and you should focus on that a little more. […] You could've approached me [in college], and I would've said yes. I already know I would've because I like to think of myself as a nice guy. I would've said, "Why not? It's not going to hurt me," which again, it might not have. But who knows down the line, 10 years from now, all of a sudden this guy's kicking me out because of a study that he found. He found it got similar enough to him and then boom, I'm out of a job." 39:24 Athlete

Another participant shared a similar concern that in a competitive environment anything that could harm an athlete would help their competitors. This participant was describing why top ranked athletes would likely not participate in combine (the annual evaluation event hosted by leagues for recruitment) because their ranking could only go down, in which case, someone else's ranking would go up.

> "So theoretically, if this [combine testing] hurts someone, it also helps someone else." 26:24 Athlete and Non-Athlete Role

Grit and Mental Health

Many participants also pointed to athletes' mental fortitude, or grit, and their ability to overcome adversity, or resilience, as being what distinguishes elite performers from other performers and a critical variable in HPR. Others spoke about how throughout the progression to

the professional level, athletes who lack the ability to overcome adversity in sports wash out along the way or early in their professional careers.

> "I want to be great in everything I do. And tennis was my life. Day in, day out, that's all I cared about. And being just good wasn't where I wanted to be. […] But there's a lot of people that want to be good, but I don't think that there's a lot of people that want to be the best of the best, the hall of fame, the greatest of all time. They're okay being good for a celebrity in their town or something, rather than worldwide. I think if you want to be the best out of the best, you can't give anything less than 110%. If you're giving less than that, then you're not going to make it, because someone, somewhere else is working harder than you. You have to be working harder than everyone else to be great." 38:9 Athlete and Non-Athlete Role

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> "For me playing at an elite level, you could see some guys, they're maybe not soft, but they just don't have the will and desire to do what it takes to be as good as they possibly can. And so sometimes obstacles can get in their way. Obstacles could be injuries, obstacles could be distractions outside of football, just letting obstacles get in the way. I think there's a way to quantify that." 35:35 Athlete

The need to capture mental health and 'grit' in HPR was also emphasized strongly by those in coaching roles.

> "But it's [athletes' motivational drivers are] one of the things that actually you'll find with elite performers [that] allows them to be closer to their potential day in and day out […] But again, I think above the neck should be equally as important as a lot of the below the neck. Then I think just breaking out some of these performance capacity, our ability, things that we can control, we can act on every day to impact our functional state, which is a point in time. […lists variety of mental aspects of performance] Then we can get into what drives a lot of that [performance]. […]Essentially, it's how we're feeling at the present moment influences our state of readiness. It directly impacts how much of our skills and abilities are able to [be] call[ed] upon or what our performance capacity is. […] It requires this daily attention and quicker to change. It's one of those things that allows us to look at how we're able to receive

> quote unquote coaching, or how we're able to show up." 42:6 Non-Athlete Role

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> "A person's just a shell and what's going on inside from a physiological standpoint, well, we've got that [shell]. We have a pretty good handle on that, but you don't know what's happening when that athlete goes home and they're sitting at the dinner table and what's their home life? What are some potential mental health issues that athlete could have? If anything, that's the silver lining we learned from COVID is, before, [if] you talk about mental health issues, and you'd be like, "Whoa! We don't have any of that here. We're all highly functional." And we all now know that that's not the case. You've got to be looking at and have an understanding of how mental health impacts the athlete you're working with and what's the motivation? Are they motivated as internal? Is it external? It's so much that and that's I think the new frontier. We're really learning so much more about it and because now that stigma has been, I wouldn't say completely removed, but it's definitely a lot less that it's an area that we need to spend a lot more time." 15:4 Athlete and Non-Athlete Role

Several athletes reported that all athletes can train physically, but it is their mental fortitude that is responsible for advancing to the elite stage. This baseball player summarized the importance of athletes' mental fortitude to be able to perform under extreme pressure.

> "For me, I think of how you perform a normal task under abnormal circumstances. An example would be, I could throw a strike when no one's looking, but when you have 10,000 people watching you and there's a batter, can I still throw the strike? Yeah, that is sports, I think. That's probably the definition that has to be included. […] We see it all the time in basketball. They can make a free throw in practice, but as soon as the game's on the line, the pressure will get to you. Human performance, it's all mental. We've been through the physical aspect. I could take every single ground ball. I could take every single swing, but if I cannot perform in front of 10,000 people, then I don't have a job." 39:30 Athlete

One example of grit was shared by an athlete who experienced temporary blindness in one eye during an Ironman competition (Record 46). This athlete reported that the loss of vision

in one eye failed to stop them from competing despite being terrified at the time that the situation would be permanent.

> "Yeah, my first race as a pro was Ironman [CITY], and I ended up having a really bizarre experience on the bike where I lost of my vision for about 10 miles. I couldn't see. Well, I couldn't see at one eye, so I was riding nearly blind, and I didn't know if I would be able to even finish. I did finish and I was dead last, but I finished. […] I didn't know what was happening, but I was like, I trained this hard, I've worked this hard to get here. This is my first race as a pro, and I'm sure as hell, I'm not going to stop if I don't absolutely have to. And so, I stopped for a second and cried, because I was just scared, honestly super scared. And then I got back on my bike…" 46:19 Athlete

Mental health issues were also reported to directly impact performance and should be factored into HPR studies. This mental health provider described how runners are at higher risks of disordered eating, stress fractures, and stigma, which impacts if and how researchers should return results.

> "…certain athletes who have a certain kind of mental profile, psychological profile who might be very type A and take that [research feedback] perhaps even to an extreme. […] Runners are very type A. They're just amazing in what they do and how they push their bodies. Sometimes, especially with female runners, they're perhaps even struggling with things like their body image, and they're using food as a tool, constricting to achieve their optimal performance, they're their kind of body type to slim down. I know males of course struggle with that too but this is just the example of a female runner. And giving feedback about "You are a person who maybe this is the nutrition plan generally that you should stick to." I can almost see them really narrowing down to perhaps only two food groups that they would eat. I don't know if they would necessarily meet the required caloric intake to fuel their body really.
>
> […] they're at risk for stress fractures because of how much load and how much intensity that they're putting on their body. And if they're not gaining the appropriate nutrition, unfortunately injury then happens, stress factors happen. […] there's stigma of course

> with stress fractures, certain injuries in certain sport, especially with running that's one." 14:2 Non-Athlete Role

Mental health experts explained how wearable technology could be leveraged to promote mental well-being by showing physical changes when athletes engage in breathing and meditative practices. In these discussions, mental health experts described how mental health interventions resulted in observable changes in physiological responses, which is data that may be captured in studies and another way that mental health could impact HPR.

> "…there's a lot more data driven opportunities in terms of engaging with things such as like biofeedback and biometrics and really be[ing] able to hone-in the skillset and utilize a little bit more of the hard sciences to help inform care [mental health] interventions [and] opportunities to help with increasing, enhancing performances. And then also, just really educating the clients that we serve in a way that make sense to them […] [biofeedback is] also something that for them [athletes] to be able to see exactly how much they can actually negotiate, manage, and control the psychophysiology pieces as well, and be able to get that back in real time has been a really fruitful experience because it also gives them an opportunity to kind of see confirmation of progress from a physiologic standpoint." 17:1 Non-Athlete Role

Several athletes discussed their personal experiences with mindfulness and breathing techniques as having direct, positive impacts on their performance. This athlete who returned to competition after giving birth describes how they learned breathing techniques during pregnancy that they found very helpful in connecting with their body. This athlete describes how breathing techniques and being able to control one's brain is an important component of elite performance that they feel is understudied. These physiological and performance impacts observed by this athlete are examples of how mental health may interact with HPR.

> "[Postpartum] I was doing specific breathing exercises and just things to heal my body, because I hadn't gone through that type of trauma before. Yeah. I feel more in tune with my body than I ever have before, which is amazing and it makes sense. […] I feel like one of the things that's not talked about and studied enough, is just

> the way that our brains work. […] I've done something before where I've been hooked up to a machine and you do some breathwork. It shows you different things and tells you this is where you need to be […] We train our body so hard, […] But what is our brain actually doing? If we could perform breathwork in a way to make our brain function at its highest, then how great could we be?" 45:8 & 45:13 Athlete

Assessments

Most athletes reported being frequently measured as part of their role as a professional athlete. Several athletes spoke about the negative mental toll being assessed took on them, particularly when actionable information was not returned to them. In addition to this finding, those who did not receive constructive feedback during the evaluation process were often the most resistant to the idea of volunteering to be measured for research without some direct benefit. The quotes below from a former athlete demonstrate how the lack of control over and access to one's information and how HPR could change that dynamic.

> "…because the teams do their own risk evaluation per player, and they don't share that information with the player. So, it's not like as a player, I know how much health I need to improve on or whatever, in their eyes. So, all the coaches, the trainers, everyone has this information, but it's not something that's available to the players. So, it would be interesting if there was a way to get the players this information" 22:25 Athlete

They continue by connecting this experience of being evaluated but having the results withheld on a professional level to the need for research to provide feedback (more discussion in the Return of Results Section).

> "I really think that unless there's a benefit to the person themself, as an athlete, you're not going to really want to give away your information. Just because it just feels like so much of your information that's taken from you already, without you having…There's a lot of information that's taken from you that you don't have access to already, just being an athlete…" 22:41 Athlete

Similarly, several athletes reported that the negative mental effects of evaluations often directly impacted their performance. This soccer player described how when they were playing at their best, their mind was clear, but the teams' assessments could have a negative mental impact.

> "…when I was at my best, you're just playing, and you're free, and you're not overthinking stuff. And I sometimes didn't like testing and things because I felt like it gets you in the mindset of over analyzing everything. I do think there is a danger of too much of that. I think there's a place for it, for sure. But the frequency and the value put on it and stuff like that needs to be in proportion and not taking away from other stuff." 30:30 Athlete

Athletes reported varying degrees of explanations being provided with the assessments as described by this athlete.

> "There is some explanation into what they're doing, but a lot of times they don't have anything to compare in what I did before. It's just, "Okay. We're doing this. We're going to do this FMS [functional movement screen] screen, because we want these numbers, and we want to have these blood samples drawn and do this testing." I would say less of an explanation and more of just, "Okay. We're going to do this." It's like I'm under contract, we're going to perform these things for the clubs or the teams that we're playing for…I've never experienced a situation where I don't feel comfortable doing something. I've never felt the need to say no. But it's definitely just like, "This is part of the structure here. You're going to do these tests, we're going to check these things, and we're going to get blood drawn." It's never, "Do you want to?" It's always, "This is your time slot."" 45:3 Athlete

Similar to this quote above, several athletes felt regular measurement and evaluation was merely necessary and equated it with any work performance evaluation process, only their physical ability was their work product. This athlete describes this sentiment, but they go on to contrast the regular work-related evaluations with the more invasive sample collection proposed by HPR.

> "I think it's the same thing. Like, "How many sales did you make this year?" And it's like, "All right, did you put on 20 pounds of

> like good weight or did you lose 10 pounds?" I think that's just normal because you're just measuring how much better you're getting at your sport. And I think athletes like that. People love it. […]
>
> It just gets a little different when you start talking about pulling muscle tissue and blood. That's where people get like scared. They don't treat it the same as... It's not like you're stepping on a scale. It's different. It is like more complicated and like scary, I guess. Anything from like, people are afraid of needles to just like a weird, I don't really know… I just feel like maybe people are watching movies and they're like, "Oh, this is what happens in the movies. When they start like taking all this information from you."" 33:29 Athlete and Non-Athlete Role

Several athletes spoke about how the mental toll became easier when they became professional athletes because the evaluations were part of business, contrasting with collegiate sports where evaluations were more personal.

> "I feel like at this point in my career right now, I'm on more the tail end of it than the start of it. I think I'd be able to handle hearing this, "This is what we believe you were." When I was younger, I don't know if I would've wanted to hear that, unless it's like, "Okay, these are the things that could come up and here's how we prevent it." If it was that information, I think it would be way different than, "Okay, your injury score is this. You're likely to have this, this, this and this, but we can't help you with that."" 45:15 Athlete

Although Olympians were not the focus of this study, one participant suggested that Olympians are more used to being measured and studied in-depth and that the risk for discrimination was lower due to there being only one national team and thus competition for athletes between teams was removed, which may alleviate the negative toll of regular assessments.

> "And then if a sport has an Olympic background, I think they're just used to being lab rats…Yeah. I mean, because you're searching for an edge, everyone's on the same team, they're team USA. There's no downside. So I think they're just used to doing that and not being part of it. I think international sports are a little

> bit more used to being monitored." 26:63 Athlete and Non-Athlete Role

Mental health providers described the need for a multidisciplinary team to inform data collection, specifically having a plan for when clinical interventions would be required. For example, one participant discussed how clinical staff would need to intervene if suicidal ideation were to be identified from a standardized depression measure. Similarly, they discussed the need for mental health providers to be included in any discussions of how individual results are returned to prevent psychological harms, such as body image related disorders. In these scenarios, it was considered best practice that the clinicians involved in any clinical services related to the research not be ones associated with the athletes' employers or formally overseeing their performance development (such as college-level support staff). This provider also noted that the need for plans to handle clinical intervention also extended to needing to plan for how sensitive data is collected and shared.

> "Well, my first thought was I think it would be terrific in some capacity for after the profile set [by the research findings] is to have an intentional conversation with the athlete and that interdisciplinary routine that hits on the [research] plan. […]
>
> I wonder the more up the road, at what point is they're filling this [survey] out and then like, "Oh my gosh, this person needs care immediately. We can't wait until this plan's in place maybe we need to do this now." Oftentimes in mental health we think about those times of needing to step in is if there's questions about suicidality self harm. So, if it were to go that route, […] there needs to be that prompt response" 14:6 Non-Athlete Role

Several athletes reported their ability to take negative feedback about their performance and/or body improved over the course of their life, particularly when it became their career. This athlete describes how negative feedback in women's sports intersected with body-image issues, particularly in college. However, they go on to say that at the higher levels, athletes are better able to cope with negative feedback.

> "I know there's some girls took it kind of personally when you tell them you're overweight or you have too much fat compared to your muscle, I know it kind of makes them feel not the best. And it's hard because he's [the trainer] not your friend and he's working for you to make you better. […] I do think it's hard in college for sure with body image too, if they're telling me, "You're overweight or you're fat," I think it does take a toll on some people.
>
> Yeah, I would say the more elite and the higher up you go, you take it more seriously. And if you are noticing that you're overweight or… it's kind of like a check system and it's not necessarily a bad thing because you also want to perform your best. And I think once you're that high of a level, you understand this is not just about making you feel bad. It's about you wanting the best performance for your team and for yourself. And I do think at the higher level, they take it more seriously, not so personal." 36:2 Athlete

One mental health expert highlighted that adolescents are most vulnerable to negative information and failing to provide feedback in a body-positive manner may lead to body image disorders:

> "I think working with youth like children and adolescents even to young adults, so even the adolescents […] I think it's really important developmentally of course to deliver this information, why it's helpful, what it can do as well as perhaps engaging with the parents or the support system in some way. Because in the case of even disordered eating it's like that doesn't start in college, it doesn't start professionally. Usually this is a little bit upstream where it starts in more of the adolescent into high school so it's a lot of that being careful of the messaging and a body and trying to empower that individual and not necessarily the message of your body's wrong or you're doing things incorrectly. Because I think that could be taken in a very negative direction." 14:3 Non-Athlete Role

Another athlete pointed out that Precision Health research has the ability to break body stereotypes and empower athletes to embrace their own body type by understanding their unique strengths instead of only comparing themselves to other athletes.

> "…as an athlete, or I see commonly that you're comparing yourself to other players, whether it's not about how you look, but how you're performing, what they're doing, and are they getting results,

you're not getting results. Okay. So if this player is winning, I want to copy them.

But with human performance that the fact that a lot of bodies need kind of their own specific formula, […] I think that would help because of the standard that's out there you want, at least in my sport. You know, you want to be tall, thin, and lean and fast and not everybody is grown that way. So, I would welcome the variety of information that's out there that could help a player that's at any level." 40:13 Athlete

Disparities

Controversial Research

When asked about any concerns participants may have related to the Alliance's research initiatives, some participants questioned whether the purpose of said research may be to 'build a superior race' or other eugenics-related ideas. This was particularly relevant when discussing the use of DNA or genetics in research. This quote from an agent covers both the eugenics concern as well as touching on other controversial use concerns voiced by multiple participants.

> "I start from the unfortunate premise that technologies that are great for the human race are also technologies that bad people have used that threaten the human race. And I just wonder. I know that there are people that stay up at night trying to think of ways to use these technologies in a bad way, unfortunately. So I just wonder, if your personal private medical DNA information gets out there, could it get out there in a way that could be used against you in biological warfare?" 25:50 Non-Athlete Role

They continued by describing concerns about how HPR could have eugenic undertones.

> "Nefariously creative minds will always be trying to figure out how to use it in a bad way, but for the most part, I think it's probably great science for youngsters. Here's another thing that I guess I get a little bit wary about all of this in athletics is, are we using it to try to create kind of little master race of athletes?" 25:55 Non-Athlete Role

Although some recruiters and team staff reported testing for athletic ability would be useful to their positions, several questioned their ability to conduct such a test in the recruitment process.

> "I'll just speak for major league players. I doubt there's ever a day where major league players are required to submit to these things [such as DNA samples]. Unless we as teams say, "Hey, your contract is contingent on submitting this information." My point is I think we would need very compelling evidence for why it's going to help us. Because again, we're very competitive. If let's say the Dodgers say, "Well, we're not going to have that requirement in our contract. Player's going to go that [way]." 7:29 Non-Athlete Role

Some participants thought knowing what type of sport an athlete was more suited to may be useful, but this was in conflict with the idea that athletes, particularly children, should be allowed to play whatever sport they chose and/or enjoyed.

> "I could see where maybe parents would test when the kids are super young and then picking sports based off of that. But that I feel like then you're going into a little bit of psycho parent, where the parents want the kids to be a professional athlete and they're trying to find the best sport. And that's where you would see parents forcing the kids into the sport, which I would not agree with." 43:3 Athlete

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> "It all comes down, I think, to mental strength and making sure that mental health is a priority. And that can start at the youngest age. And that's the thing you're not overworking, you're not hooking people up to wires and injecting anything else it's all about, "Okay. What does matter? What are you able to get and make sure that happiness and making sure that their goals are their goals it's not society goals. It's not their parents' goals. It's not something that's driven into them on their pressure breaks. And they feel like they're carrying the whole world on their shoulders. And then if something happens, they didn't let themselves down, they didn't lose the race, they lost the race for the sponsor, their parents or anything else. And, and I think, I think across the board, we can do so much better." 28:49 Athlete

Access

In the same vein as eugenics, issues similar to ablism surfaced in several different ways. Some raised concerns about accessibility to sports if there was a test that could determine who would be good at sports. Several participants felt this shift would change sports significantly.

> "I mean, it [testing negative for elite ability] would definitely have doubt in you just knowing you're physically not up to it. There's people that are faster, stronger, smart, everything across. You're not going to make it. What's your plan B? What's your plan C? You'd be devastated. I think having hope and having those dreams are everything. I mean that's from my side." 28:24 Athlete

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> "…maybe science will eventually be able to figure out through that DNA of an athlete whether that's there or not. I hope not. I think that's [unknown potential is] magic. Once again, science is all based on knowns. If it's already known, "Hey, we tested this guy's DNA, and he's going to go under two hours in a marathon." It's like if that's known, why do we even have a race" 15:41 Athlete and Non-Athlete Role

Several stakeholders discussed how athletes with treatable medical conditions or conditions unrelated to performance faces negative impacts on their draft rankings, contract negotiations, and potential for employment, despite physicians having cleared them for play. This problem was best described by an agent whose client had atrial fibrillation (a-fib), a treatable heart arrythmia, who was trying to be drafted at a time shortly after another athlete died of sudden cardiac arrest while playing the same sport.

> "So, anytime you [an aspiring athlete] had a-fib, teams were running away. I had a client, actually had got removed from about 26 different draft boards, to where he wasn't going to be drafted. My job became, how do I figure out, first of all, what's wrong with him, the a-fib, and figure out if it's something I can manage […] To make a long story short, the kid ended up getting drafted to second round, played [3 times more than the average career] years in the league. […] But, understanding the medicine and science behind it made a big difference in getting him there." 32:39 Non-Athlete Role

Similarly, several athletes feared that research results may restrict them from playing sports if a medical condition was identified.

> "I wouldn't have wanted to know [bad results] if it was going to slow me down… They might come back and say, "This guy's going to die in a week," and so... somebody tell him to stop."" 5:21 Athlete

Accessibility to sports was discussed frequently, and most who raised concerns that the research could be limiting also pointed out that in other ways this research could also expand access.

> "…there's a lot of ethical questions about trying to decide at a young age whether [a child] is meant for something and whether that's a good thing to foster those people maybe, especially underserved communities where the money isn't there. And if you found out that there was a real potential for greatness there, you could actually serve that kid who otherwise would not get a chance. But there's also a tremendous amount of pressure if you put it on people that they genetically should be great and then they aren't […] You just didn't have it. Versus you did have it and you blew it. Which is a whole different can of worms." 31:31 Non-Athlete Role

Diversity

The need for the research to promote equitable representation amongst participants was also brought up.

> "And we talked about the journal article because it featured, I don't know, 60, 80 patients with elbow issues, but they were all white males of European descent. And so, just acknowledging that there's this huge discrepancy in what we know, and a lot of what we base things on, even in medicine and not just sports and performance is based on a lot of research done on white males. And so, when we talk about all this stuff, if anything, actually doubling down and reinforcing or redistributing this information resources geared towards Black and brown people, people that typically have not been included in this, that almost sets it more equal than anything. So, I think all that stuff is really, really important." 13:50 Non-Athlete Role

Diversity with regards to race and ethnicity along with culturally appropriate research was emphasized by several participants. A mental health provider spoke directly about the need for the research to be culturally sensitive, pointing out that historic research abuses and variation in religious beliefs should be incorporated into the research designs and practices.

> "You've got the cultural implications and the trust within the medical community, you have historical factors. What has been their historical experiences with quote unquote medical providers, and how does that translate into the willingness and desire to participate in research that has some medical elements to it […] just looking at the spectrum of diverse athletes across the professional lens, there are cultural implications when it comes to engagement with medical communities. For example, you can take

> the Black or African American, or even [an] African descent community, and a number of different unapproved research practices that have been done. And there's a lot of reconciliation that is happening with that community. You can also take individuals who might have religious backgrounds […] that doesn't necessarily allow for drawing the of blood, and things of that nature. So just all of those things need to be taken into consideration and the approach to the athlete invitation to participate." 17:14 Non-Athlete Role

Discussions about representation included topics around the structural racism in sports leadership, abuses within organizations that actively discriminated against athletes of color, the frequency of sports as a means to escape impoverished environments, and the historical abuses of research on various races and ethnicities.

> "…when you start talking to me about genes or genetic things, I would start thinking athletes would be worried about those issues in a variety of different ways, including racial stereotyping. We have an unfortunate history in this world of genetic classification, and so there may be some sensitivity around those issues." 12:32 Non-Athlete Role

The importance of diverse representation in research participants was also discussed in how it relates directly to science. This participant discussed the potential disparities that could arise from research that was not equitably designed and conducted. They also pointed out the structural racism that prevents diverse representation in positions of power and authority.

> "I think the health equity component of any research is just so crucial. Especially as it relates to representative sampling, making sure your research population represents the cohort you're opining on, and everything down to the wearables you use. Would a data collection methodology have some sort of disproportionate impact if you had darker skin tones?
>
> […] I think we have one black team physician. Putting the coaches' issues aside, the providers don't even represent the patient population and we're doing a lot of work to change that right now, but it's not easy." 21:73 Non-Athlete Role

Several participants reported interest in seeing the Alliance include under-resourced communities with higher risks of comorbidities, such as low-income, obese children at high risk for Diabetes, in the research to improve access to sports and offset the gap in resource allocation to researching elite performers.

> "…especially our women's [soccer] team and knowing them more on an individual basis, stuff a lot of them care about looking at people of disadvantaged backgrounds, whether that's culturally, a lot of the LGBTQ population I know is very important to the women's national teams specifically. But just looking at groups that maybe traditionally have been left out of some of this new and innovative stuff and making sure that all groups get access to it […]maybe it is altruistic a little bit to say, look, we're going to be using this [health] information or as part of doing this [HPR], we're also going to be reaching out to these groups that maybe couldn't afford it, or couldn't be involved just on a pay-to-play perspective […] I do think that is important, but purely to answer your question, I think it's just more of an equitable approach." 13:9 Non-Athlete Role

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> "We have a massive obesity problem and movement problem and mobility problem in our country right now. […] What's the bigger picture here? What are we really trying to accomplish? If it's just to say that these people [elite athletes] are outliers, and this is why they're outliers, that's awesome. But, if we're really talking about population health, wellness, interaction, integration, societal change, behavior change, that's what I get worried about […] how the information, once it is internalized, gets leveraged to inspire the community. And, I feel like more often than not it's the Facebook or Instagram or Twitter community where life is perfect, this is how you should be. And if you can't get here, then you suck and you're always going to suck. And, I'm just really tired of the unethical utilization of that information to beat down a society that's already beaten down in a lot of ways. […] so, that's the part that I get worried about with all these resources to help out people who have a lot of resources already. These big leaders don't need more resources. They have plenty of money…" 11:24 Non-Athlete Role

While many researchers may be cognizant to these problems, including the research team for this study, diverse research recruitment is a multifaceted issue. Despite this study specifically

seeking participants from a wide variety of backgrounds, lived experiences, and races/ethnicities, this study's participants were primarily non-Hispanic White (37 of 42; 88%). Reasons for this disparity may stem in-part from seeking key informants, who were more likely to have higher educational attainment, but disparities in educational attainment also speak to the structural racism athletes of color face in life. Another factor more directly related to the Alliance was that the researchers were not all 'sports insiders' and, therefore, relied heavily on nominations from Alliance members and participants.

Wealth

In addition to the discussion in Athlete Characteristics Section related to variability in resources amongst elite athletes, several athletes voiced concerns that this research would further divide well-resourced, financially secure athletes from under-resourced athletes. They reported that a likely outcome of this body of work would be useful interventions that once made commercially available would only be accessible to the richest athletes (also related to Athlete Characteristics Section and Commercialization Section).

> "So people would definitely be looking to use this as an advantage as well, for sure. Being able to regenerate faster, but then you're looking at, okay, so you're coming through the ranks and not every athlete has a ton of money to begin with to be able to pay for that stuff. It's also how accessible would it be, because then you're dealing with, okay, all the top players are going to be able to stay at the top because of all this good technology. So, then there could be an even greater divide within sports.
>
> […] So it [HPR] could be going this way, enhancing the performance, enhancing this stuff. It could create even more of a divide between the people who are already at the top and can afford to get this. Because obviously when this comes out, if there's something that's found that you can do, whether it's taking out muscle and just getting that regeneration, it's not going to be cheap, especially to begin with, […] [it] is never going to be affordable for the average person." 43:9 Athlete

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> "Obviously, you can play out a devil's advocate and say, "Well, is this going to be equitable? Are the rich, so to speak, going to get richer and people that don't have access to fall further and further by the wayside as we talk about looking at younger athletes?"" 13:14 Non-Athlete Role

One athlete shared their story of living in their car to be able to afford to compete in tournaments. This participant went on to speak about how they would be willing to participate in any research that could help them train and perform better.

> "When I first started out on the professional tennis tour right out of college, I actually slept in my car a lot. I was eating canned sardines and stuff like that because I was on a very strict budget. I was very poor out there. So, this is really dear to my heart, having better resources and stuff like that, better nutrition, better place to sleep, things like that. They all pay a difference, but you have to do what's in your means, obviously, when you can." 44:18 Athlete and Non-Athlete Role

This story contrasts sharply with the example of athletes who travel with hyperbolic chambers (43:9) and demonstrates the extreme gap within professional sports. This comparison also strengthens the concern that under-resourced athletes may be less risk-adverse if they believe they are gaining access to technologies and resources they could otherwise not afford.

Women

All stakeholders who worked with Women's sports agreed that there was insufficient research on female athletes as they are not just 'smaller men.'

> "I also then say research traditionally has been done on men. It's a disservice to 50% of those people on the face of the earth. Women are not small men." 42:5 Non-Athlete Role

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> "So most studies have been done in male rodents or in cis white men. And so there can be a lot of differences. I mean, studying women in terms of their metabolism and how different drugs are metabolized, studying women throughout their lifespans, studying women at different phases of their menstrual cycle, all of that has barely been touched. These studies from 2014 to 2020, looking at

> the top sports and exercise science journals, only 6% of the studies were done solely in women. So we're extrapolating a lot of data from other groups into women, which I think can be dangerous knowing the differences in terms of metabolism, physiology, endocrinology." 20:43 Non-Athlete Role

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> "…women are tremendously underserved when it comes to performance research, and I think, and again this is speaking from my experience, if you look at the majority of research that's available simply in the realm of exercise science, I think elite female athletes are even more underserved than just females alone." 47:25 Non-Athlete Role

Similarly, research was reported to be severely lacking in the perinatal period, where pregnancy was often said to be the end of one's career.

> "I think there's this fear that can be put into a lot of athlete's minds that you shouldn't push yourself. I've heard that you shouldn't squat as deeply, and you shouldn't run when you're pregnant, and you shouldn't do these things." 45:8 Athlete

Participants with personal experience being or working with perinatal athletes discussed the perceived fears in both the sports and research communities. Several reported that due to the lack of scientific evidence for this stage of life people feared working in this space as it could result in negative outcomes during pregnancy, specifically miscarriage. One mother and active professional athlete reported receiving fear-based advice. This athlete also said that this type of misinformation was why most female athletes to believe that they could not play or return to play if they were pregnant.

> "I think a lot of it is fear-based from stories that people had heard of. […] A lot of it when I first got pregnant was "Don't do this because.." they would literally say, "Because you're going to miscarry." I was like, "What?" […] The science aspect, I met a trainer who was trained in pre and postnatal training. […] He was like, "You can do everything that you did before. We want to do that as much as possible because when you come back, it's going to be easier." At that time basically, lifted and was active until the

> day before I gave birth. I think it was a huge component to my recovery and how fast I came back after I had her." 45:10 Athlete

Their trainer also described the need for more research on perinatal athletes.

> "…why are athlete moms not given this level of direction [compared to men]? But I think it has gotten a lot better with time. I think there's still a lot more room to continue to expand. […] I think there's a little bit of a conservatism for research with pre- and postnatal stuff because nobody wants to be responsible for any bad outcomes. […] We don't want to put any babies in danger or any moms in danger. But I think it's still an important area that there's a lot of benefit that can be gained from additional investigation." 47:14 Non-Athlete Role

Interviews were conducted around the time of the Dobbs v. Jackson Women's Health Organization Supreme Court ruling, and it was noted by one researcher that following this decision menstrual data would now be a sensitive type of data.

> "I think that we can come up with ways where we can have our athletes get their menstrual cycle history in a way that is very protected where they're not going to get arrested for having an abortion. I certainly hope so. I will do everything in my power to prevent that from being an issue because I think there's just too many women in science that would lose their mind if we couldn't stand up and protect people's rights in that way." 20:32 Non-Athlete Role

One participant pointed out some of the historical consequences to not studying women equitably.

> "I think about the things that often come up, which are the lack of studies into women's bodies when compared to men, the absurdities of people not being able to do CPR on women, because they've only used male dummies and things like that, that you hear about. I also think about how recent it was that there were pseudoscience that said that women couldn't run marathons because their uterus would fall out. Couldn't ride horses. Couldn't do distance events. […] It's like, here's what we think about women, and since we didn't bother to do the research, we'll just stick with this." 31:2 Non-Athlete Role

Global Disparities

With respect to the impact of this research and addressing global health disparities, participants questioned the Alliance's ability to equitably share samples and data via the stated partnership with UNESCO. One participant pointed to lack of resources being a hindrance to accessing and/or utilizing research data or samples (Record 14).

> "…if you have, I don't know, researchers in the Congo and they just like want to see what's out there and they do the research and say that they do this on their athletes and hey, they need the nutritionist and the mental health provider and the PT person, whomever's on that team to really optimize the performance of the athlete. Well, say that team or that person in the Congo who's doing this for the athletes they don't have access to any of that.
>
> And so, then you have somebody who is, I don't know, in New Zealand, who's got great resources and able to after looking at that can say this is what we need, and this is what we can invest in to compete and have our athletes perform at their optimal level." 14:13 Non-Athlete Role

Those who discussed such concerns identified how equal access instead of equitable access may further drive disparities at the global and scientific levels as well-resourced researchers would be at a greater advantage in both discovery and implementation than under-resourced researchers.

Other concerns regarding disparities at the global scale were human rights concerns. For example, members of the LGBTQAI have long histories of being discriminated against in international competitions.

> "…the gender piece I think is extremely important, and then you also have to be mindful of the transgender piece because that's going to also have some different implications for perhaps and results and things of that nature. I think there are certain sport types that tend to have more of an affinity for engaging in such practices as this in terms of research and getting data analytics and things of that nature, where there are just some other sports that are just […] analog, I should say. Just being mindful of the different types of sports that come into play that might have a little bit more of an affinity for the progressive analytics pieces." 17:33 Non-Athlete Role

A transgender athlete researcher noted that sharing information of transgender athletes with countries that lack protections could result in risking the confidentiality of these athletes, which could potentially endanger their lives (Record 27; relates directly to the concerns in the Section 4).

> "Certainly, there are a number of countries in the world where trans people aren't welcome, and that's to be put quite an understatement on it. There are countries where it's considered more honorable to kill a transgender sibling, than to allow them to live and bring shame to the family. So, sharing information that can help people identify potential trans athletes with people in those countries, there's a significant risk there." 27:17

However, this participant reported that this research could help inform regulatory thresholds and policies as many cut-offs for factors like testosterone are still arbitrary.

> "Certainly, in terms of the research that I do [with transgender athletes], the most important question is what does hormone therapy do to the performance of transgender athletes? Both in the case of trans women where there's testosterone suppression involved, and in the case of trans men, where there is addition of testosterone provided. Seeing what happens to elite athletes, and then, there are very few trans elite athletes, but there are some. And exactly how their performance changes, with hormone therapies, is something that I know not just the athletes themselves, but sports governing bodies all over the world, are very interested in." 27:35

This participant also identified certain data points that would be considered sensitive to the transgender athlete community, particularly surgical procedures.

> "Well, certainly in our field of transgender athletes, one of the things that we're interested in is, what surgical procedures they have had, because it affects things like hormone levels, hormone therapy regimens, et cetera. So, it is something that is of importance. And in our questionnaires, we don't directly ask these questions, but again, there are certain hormone therapy regimens for trans women before they've had surgery, and different ones after. If you're asking them about their hormone therapy regimens, then you know this information. And I don't think that under any circumstances, is a member of the public entitled to know about

> the surgical status of any of the athletes that I have dealt with." 27:15 Non-Athlete Role

A lawyer spoke about the discrimination and failure to use scientific evidence in determining the case of Caster Semenya, who was found not guilty of doping as she was shown to naturally produce higher levels of testosterone but was still barred from competition.[232,233]

> "That really wasn't a case where the technology drove the decision-making at all. That was a case about discrimination against certain women, and that's what drove that decision. It was discriminatory to begin with, and it's still discriminatory. The fact that they can collect more scientific information really hasn't informed the debate, because in my view, science is not leading to a proper decision there." 12:19 Non-Athlete Role

This person went on to juxtapose this case with the case of Blake Leeper, a Paralympic athlete, where scientific evidence was offered to estimate the athlete's biological height compared to his height with prosthetics was based on data and samples that lacked Black study participants who would be more similar to Mr. Leeper.[234] These examples show how science has been used in regulating testing and claims of unfair enhancements, and they also highlighted how discriminatory practices could remain ingrained in both sports and science without proactive efforts to include diverse participants and produce generalizable results.

> "That [whether there are racial population differences] was an issue in the Blake Leeper's case because the studies that were done, what they were trying to do was predict the size of the length of legs that athletes would have who were double amputees, if they had their legs, in order to decide what would be the proper length of their prosthetic legs. And in doing that, in the Leeper case, they used an all Caucasian and Japanese sample and applied it to Blake Leeper, who is an African-American athlete, and there were real issues as to whether or not there were population differences in terms of average leg length." 12:32 Non-Athlete Role

Return of Results

Human Performance Research

It should be noted that HPR was framed in this study's interviews as being intended to improve athletes' health by ultimately learning what factors are associated with achieving peak performance, avoiding injuries, and recovering from injuries faster. Examples of performance improvements from the interview guide included customized training plans that may provide nutrition, sleep, and recovery guidance. This research was framed as ultimately leading to performance improvements for athletes and the public more broadly. As a result of this framing, the expectation of return of results may have been inadvertently implied. However, nearly all participants expressed that there would have to be 'something in it for the athletes' for them to be willing to enroll in a research study.

> "I think that it's going to really be for a lot of these guys, they're going to say what's in it for me. That's going to be the little voice in their head. Again, I do think if the protections are high enough in terms of it not being identified, 'used against them,' and the benefits are understood more to like, "Hey, pay it forward," kind of thing. A lot of athletes, they definitely connect with that idea of making it better for the next athlete." 7:50 Non-Athlete Role

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> "I think athletes are generally curious about their body, that everyday they're evaluating their capabilities for that day and they want to understand why they're getting better, or how they perform, or even gaining any sort of edge. So, I think if there's immediate feedback to them, I think some athletes want to pay it forward. But I think generally when you have a short career window, you need to maximize that. I think there's some immediate feedback that whether it's vetted or not, they want to know about themselves and provide some context, they're usually interested." 26:4 Athlete and Non-Athlete Role

Nearly all participants reported that any results should be returned directly to the athletes, and that the decision to share research results with other parties should be the athletes' decision

alone. Several participants described sharing research results as being the athletes' stories and they should decide with whom and when to tell them.

> "Maybe it's just the players, their own little biometric card, right, of what they need. And then, they can, hey, listen, I noticed that, or I got stuff on this off season…And, they think that I benefit more from X, Y, or Z. And, that's what I want to go after then, it's the player's story to tell. And so, I think that is the most efficient pathway to have the players know that it's about […] them, it's for them, it's in their control, it's in their control to figure out. That's probably the best way to go about things" 11:29 Non-Athlete Role

As discussed in the Impact of the Research Section, a mental health expert explained the need for multidisciplinary teams to facilitate any return of results to ensure athletes are supported throughout the process.

Costs of Research Participation

The need for direct benefit was discussed as a cost-benefit analysis that accounted for the athlete's giving of their time, energy, privacy, and possibly mental well-being. Most athletes spoke of the decision to enroll in HPR as being a cost-benefit analysis, so any research that required time and effort was expected to return direct benefit to the athletes. Research participation would require time away from training or recovering, which are too valuable to them to do without direct benefit.

> "I think someone who signs up for that type of research, so it's voluntary, it's an investment, a huge time investment, and privacy investment. So, we're exposing all sorts of nuts and bolts. The impact is whether or not, A, first, I mean you contribute to general understanding and knowledge, there's benefit there, there's psychological benefit, there's societal benefit. But also, if they have personal returns in terms of understanding their own performance, I think that that can be quite helpful. Now, psychologically, if you find out negative things because of that, that can be detrimental as well. So, you probably have to figure out how to navigate that I'm sure from a counseling standpoint, not unlike genetic testing or otherwise." 41:11 Non-Athlete Role

Athletes' time was often discussed as a rare and extremely valuable commodity.

> "As like a current professional athlete, I would say I'm not going to go out of my way and spend time and effort for something that isn't going to directly, I guess benefit me, just because of the schedule and everything like that and how busy you are." 22:39 Athlete

Athletes frequently spoke about research participation as a means of gaining access to a competitive advantage comparing that to the risks potentially associated with sharing their data and samples. This trainer highlights the need for HPR participants to directly benefit from investing in the research process.

> "[If] I sign up for it [HPR], what am I going to learn for it? How can I act on it to give me a better competitive advantage to achieve my goals, my dreams? That's where it has to be for someone to want to consent in. Otherwise, it's like, why should I go through the trouble?" 42:27 Non-Athlete Role

They continue by describing the long process of obtaining verifiable research results and contrasts that to the testing already being done where athletes have immediate access to useful information.

> "[...] The challenge with kind of traditional research is you're going to tell that player 24 months later. […] you have to take the data in, you've got to run it, somebody's got to pack it, and you got to get it out. It's such a forensic thing, but today's athlete and today's clubs and organizations, all of them are treating N of one. All of them are doing some form of evaluation through monitoring or evaluation daily. A lot more organizations are being set up to intervene as part of their kind of standard operating procedures. That's happening relatively fast […]
>
> The majority of what we're talking about at the elite level is competitive advantage. So long as that competitive advantage is there, the investment and the rest drive behavior…" 42: 28 Non-Athlete Role

Although a few participants indicated that altruistic motivations alone may be a sufficient benefit for some athletes to participate, in general, most participants echoed the expectation that athletes would likely only participate if they received a direct benefit to themselves, usually described as either gaining a competitive advantage or receiving a personal result.

> "…it still just goes back to, this is my whole life, and I'm training for it. And if you can't help me do it, help me get to where I want to go. I'm not going to help. And that's just the truth of it" 33:49 Athlete

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> "I really think that unless there's a benefit to the person themself, as an athlete, you're not going to really want to give away your information. Just because it just feels like so much of your information that's taken from you already, without you having […] There's a lot of information that's taken from you that you don't have access to already, just being an athlete." 22:34 Athlete

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> "It's hard to say, "Hey, sit down, take this test," and then we don't give you anything. Forget even money, but it's like we don't tell you, "Hey, this is what you're good at. This is what you're bad at. This is how this is going to make you better." 7:16 Non-Athlete Role

Participation during an athlete's professional years, or once a professional career was anticipated, was perceived as being much less likely due primarily to risks outweighing benefits and their limited time. The vast majority of participants reported that rising and peaking professionals would be the least likely to participate; however, most speculated that those nearing the end of their careers may be more likely to participate in research (see the Life Course subsection within the Athlete Characteristics Section for more details). This athlete explained why athletes later in their professional careers may be more willing to participate in research by demonstrating the differences in 'what's at stake' in dollars.

> "I think if that study [hypothetical injury risk prediction study] was to succeed, it would have to start with guys who were already established and/or made enough money to where they're feeling comfortable in their career and their choice.
>
> […]a guy who's made a million dollars in his career, that sounds really nice and well. But if he does the study, he's risking 10 million. Where if you go to the guy who has already played seven, eight years and made 100 million, he is more likely, I would say, to

> do the study because 100 million is absurd wealth where he may be risking 10 more million, but he's okay. He's already set himself up.
>
> I think for this study to really take off, […] my initial thought is if I'm not secure enough in my bank account for my family, then I'm probably going to stay away just in case the data is so good that it exposes a weakness that I might not even be aware of." 33:15 Athlete and Non-Athlete Role

Some athletes, however, expressed that even at the peak of their career, they would participate in research if they thought it could help them improve their performance.

> "Looking at it, athletes at peak levels are trying to figure out little advantages that again, get your 0.1% improvement on whether it's recovery or what have you. So, I see a big advantage and I saw that as a player in the NFL, figuring out ways to make sure I was ready to go each and every week. Our sport has weekly games, so just being available. Part of your ability is your availability. They like to say so, to do that is super beneficial." 35:3 Athlete

Another cost less frequently discussed was that the financial risks related to research participation may be amplified in the professional athlete cohort. Athletes who receive high annual salaries, usually team sports, bear higher financial impacts if faced with adverse events during the research study, particularly those that could impact their abilities to perform (Record 6).

> "The downside of an adverse reaction is higher...I think the risk of an adverse reaction is probably roughly the same. The potential downside in terms of economic losses and that sort of thing is higher." 6:34 Non-Athlete Role

Unlike team sports, individual sport athletes pointed out that injuries or events that inhibit their ability to compete would cost them financially.

> "…it's tough. If you're not playing, you're not making money." 43:11 Athlete

Although these financial risks are more easily calculated for athletes at the professional level, the risk to future earnings is applicable to athletes striving to become professional.

> "I just really think it comes back to everybody's always trying to make the most money that they can. Everybody's always worried that someone's going to come in and give reasons why they shouldn't. And so, I guess the college athletes have as much to worry about because if someone were to come in and say, "Hey, we've learned that this, this and this factor mean you only have three years on average to make it. And so, we're not going to pay you for a five-year deal when we know that the average expectancy is three."" 18:18 Non-Athlete Role

Study Results

It was generally understood that not every research study may provide individual results in a timely manner, but many spoke about the expectation for direct benefit of the research activities themselves, such as gaining access to technologies and experts not otherwise available to them.

> "If you were having them [famous athletes] come in-person, the reason they would come would be to get access to some of the best and brightest in the world…That's some of what they would gain. I would potentially do it to show up and meet 10 people that I don't know how they might help me, but I know they're really good, and it's people that I might not meet. Right. But if you show up and it's sterile and they're like jump and go [do] this, they take some blood and get you out of the door and thanks for the bank, they're not going to be happy about it. Right. One of those models takes more and money and energy, et cetera." 26:69 Athlete

One athlete indicated that at the elite level, research interventions should be well-tested and have significant evidence of effectiveness, similar to concepts of therapeutic misconception.[226,228]

> "I think if you're at a high level to where you can't risk any setbacks, that it would be hard to convince you to do it. Unless you had really sound research that was clinically proven. You had peer reviews and lots of stuff to compare it to. I don't think something new, they would jump on." 38:12 Athlete and Non-Athlete Role

Another cost to participation, discussed in the Athlete Characteristics Section, was that regular measurement and evaluation was reported to take a mental toll on athletes. In a similar

vein, many spoke about the balance required for returning individual results as information that was presented as being deterministic (such as a genetic condition) or not body-positive could have negative mental health impacts and subsequently impact one's performance negatively. This athlete describes how body-image concerns vary across types of sports.

> "…compared to some other sports in college, I lived with a bunch of cross-country runners, and it was just very different [from soccer]. Sometimes just things like weight and body image and stuff like that. I mean, soccer has its own issues with that, but I wonder how sometimes being evaluated and measured and stuff like that can mentally affect athletes. Especially given whatever pressures they have and preexisting things they have and stuff like that.
>
> […] I remember being like, "Well, okay. My body fat percentage isn't that high. That's good." But I could see how that could be an issue for people could get obsessed about that." 30:30 Athlete and Non-Athlete Role

In addition to costs of time, energy, and exposure of personal information, sample acquisition was one concern raised often by athletes. Several athletes spoke about common fears of needles, while some speculated about much more gruesome invasive procedures that would be unacceptable for them.

> "The only thing that when I think of human research, are they going to cut you open and is it going to be invasive? That's the only thing that makes me feel. Obviously, I'd probably say, "No. Can't cut my head open and look into my brain while I'm still breathing." But other than that, I can't really think of anything that would make me uncomfortable or not interested in it." 45:14 Athlete
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> ~
>
> "Just as long as you don't have to cut off my [six] pack or my arm." 28:18 Athlete
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> ~
>
> "I do think there could be cases where people don't fully understand like what they're consenting for and possibly something

> is involved in some sort of research that they don't approve of. But whether they know that or not, I guess, is what it is. I honestly don't think many people would have a problem with it, but I do think stuff, I don't know, I'm thinking stem cell research or research on embryo, stuff like that. If that stuff banked away and maybe stuff is done with that, which is not... I imagine you'd be taking blood samples and maybe some muscle tissue and stuff like that, but I could see where it could go potentially." 30:20 Athlete and Non-Athlete Role

Although no participants were excited about invasive procedures, most reported being willing to tolerate blood draws and muscle biopsies as long as they did not impact their ability to train or compete.

> "Yeah. I mean, for me, I don't have a problem with it because I have the trust in scientists and doctors, and I wouldn't think that they would want to do something to harm us. I think that they would want to help the next generation. So, if I'm able to donate time, or samples, or knowledge, or experiences to them to better shape the next generation to make my sport rugby or any other sport or life better for the next people, I'll I'll do that any day of the week." 28:19 Athlete

Similarly, research participation, even with potential for direct, personal benefit, was overwhelmingly not likely to be successful around competitive schedules.

> "During the off season, it's a lot easier to get athletes to participate and stuff and it's a lot more challenging when it's in season especially as big events are coming up, and you see swings in athletes' performances based upon where they are, coming up to their goal events and things like that, and a lot of times, it's a lot of travel. […] it may make them a little less somewhat apprehensive in participating depending upon how invasive you are and what you're looking to collect. Two nights before world championships or the week before world championships, that's a tough time to get at when a really elite athlete who's got a realistic shot at winning." 15:1 Athlete and Non-Athlete Role

Individual athletes, however, reported having smaller windows of down-time, and they reported research may conflict with their recovery needs. These potential costs were typically discussed in weighing the decision to participate in research.

> [Asked if they would participate in research outside of competitive schedule] “Probably not. I got two weeks of no riding and it's like, I'm going to savor those two weeks. And too, it's... even when you're off season, it's like... So again, this is anecdotal, but I once heard... One of our team doctors once said "It's important to let your heart rest," and so I would try and do as little as possible whenever I was in the off season. I've usually made it a week before I just got stir crazy, but I guess to answer your question without being long-winded, I don't think so.” 34:12 Athlete

Biobank

A biobank, on the other hand, was presented as a traditional research tool that was typically a means of facilitating additional, unspecified, future research without any results or communications to the athletes after enrollment. Despite efforts to make it clear that biobanking traditionally does not provide either individual- or study-level results, athletes frequently reported that being in a biobank would be a means to learning more about how their body works and sentiments similar to therapeutic misconception.

> “I'm for all of that [participating in a biobank]. I mean, I'm always happy to be tested, but the problem for me is that they can always find something wrong with me. Always. Whether it's skin cancer, or whether it's the deformities of my feet, or the fact that my hands don't work. I don't mind being tested, I just don't want anything to slow me down. I keep going. I know that they can find ... They start testing me, they're going to find something. They're going to say, "We got to do this. We got to to do that," but I feel fantastic.” 5:19 Athlete

Most participants acknowledged that altruism would be a reason for participating in this form of research, but it was still usually weighed against the costs and lack of direct benefit for participants.

> “I don't know if the buy-in to doing it [participate in a biobank] knowing upfront that they would not receive information or insight from contributing to it, especially when there has been such a huge movement in the trend of […]sense of agency. That's just something to be mindful of. I mean, there's always a sense of altruism. And so being able to contribute to information that might help the greater good or help the larger society, but then again,

> there's also this huge swing in the pendulum of movement in terms of athletes privacy. And being able to not just solely be seen as an athlete, but seen as a whole person. I think there's some contention that might be present." 17:9 & 17:10 Non-Athlete Role

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> "I guess I'd look at it for the good of your high performance, because if you're not going to get the results, you don't know anything individually about how it could help you, it's going to the general idea of how human bodies perform. Going back, I guess, to the beginning of the anonymous part of it is, I don't know, maybe it would take a unique person [to agree to participate]. I guess I interpret that as something being very selfless because you are not going to be able to get results. And so, you're […] giving away your data, but you're really just helping enhance the information that we already have." 40:20 Athlete

However, few athletes reported being content with not knowing what their samples and data were being used for or learning about the studies' results. This sentiment was often tied to either an increased sense of agency amongst athletes and/or general lack of time.

> "I think they would be highly skeptical. The lack of control is not something most professional athletes would welcome, especially when it comes to sensitive health and genetic data. So that would be a hard sell." 26:27 Athlete and Non-Athlete Role

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> "Yeah. I maybe if you wanted, maybe have the option of, can you share what you've... Because I would want to know, personally. So, if you go one way, then it's like, "Well, I want to know what you studied about me. Tell me where I fit." That's what I would be interested in." 33:6 Athlete and Non-Athlete Role

Many athletes expressed the desire to receive results from biobanking research. It was unclear how many would be satisfied with study-level results versus personal results.

> "I mean, my initial thought is I would not be interested in this [biobank] unless I could see the results. I guess it feels a little weird just having your medical information open for them to examine, and not that I don't... I don't think I would be... If I got other option, I wouldn't be too interested in it." 22:70 Athlete

One athlete said that the lack of feedback from the biobank could lead to resentment and recommended making the biobank function as a partnership (Record 16; see the Engagement Section for additional discussion).

> "So, if there's not really result given back to the patient, if there's not good communication, I think resentment can build, and frankly, you'll never get sort of longevity in what you're trying to do. If there's a way that the patient or player is included as almost a partner in this and ongoing discoveries are shared, I think that's the value. Yeah. I think that would be really important." 16:35 Athlete

Only a handful of athletes reported being fine with not receiving information about what kinds of research was being conducted or results of the research studies in which they were included.

> "I think one of the main reasons they would do a study this big is to get that feedback, to see how they can improve their performance and what all they can do. And like you said, they'd be getting that from Alliance [via a HPR study], but then if they put into a biobank, all the stuff after that is kind of nothing. You don't see any of it, you don't know what's going on. But I think either way it's useful because initially you do get some feedback and you're already in this research study, so why not let it go and help other researchers to improve other aspects of people's lives and what they can find out from that information, I think would be helpful regardless if you know what's going on or not." 36:27 Athlete

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> "I don't really have an opinion about it, because like I said, it's the benefit for the study. It's not for me. It's not for someone specific or whatever. So it's just benefiting the research for the future. So I'm okay with that. [Asked about satisfaction if their participation only benefits future research] Yes, because I feel like in today's society, we do things for the benefit of ourselves. We're very selfish. And so sometimes I think about, I want to do it because I want to, I don't know, make someone else's life better in some way in the future because they have more information about sports and medicine and things like that. So I guess I'm giving back, I would say." 23:36 Athlete

One researcher reported that returning study-level results would be relatively easy if the Alliance simply shared publications, but managing individual results, although it would likely boost recruitment, would be very expensive and time-consuming. This concept of returning individual results also links to discussions about giving athletes more control over how their samples and data are used in the Consent Section below.

> "I think in a mass setting, if the participants want to be notified of a publication or journalize research results, I mean, obviously that's easy to do. On a one-to-one basis, […]I think that would put more onus on the researchers and make tracking of potentially thousands or tens of thousands of samples in patients who all want their results possible, but that may help enrollment. I don't see it as a critical portion of the process unless you want to throw the kitchen sink at it and try and improve enrollment as much as possible […] if from an enrollment standpoint, it would be nice, what's in it for them, but boy, that is a huge logistical challenge, in my experience, and can lead to a lot of problems. I'm not sure it's worth overcoming the current standard community practice of just banking it and not having access to their information, right? I mean, part of it depends on how much money you've got in your funding mechanism, right? So if you've got 10 FTEs to deal with, 10,000 phone calls about what does this mean, then maybe it's worthwhile. But if you're running a barebone ship, I'm not sure that the risk of all that data and releasing it individually to patients is worth it." 10:13 & 10:31 Non-Athlete Role

It was also recommended that participants receive early access to study results as a means of offsetting the lack of individual results in secondary research.

> "If there's any elements in there they could be shared and could be given back to the athlete or it could be a, listen, we're going to study this, but you're going to get the first look, a preview of what the results are as a participant in this study. I think those kind of things potentially could help." 7:16 Non-Athlete Role

One athlete specified that the results would need to be related to performance or health, otherwise, they reported that some of the scientific findings may not be understandable to the general public.

> "I think it depends on what research is being done. If it were other performance-based research or health-based, maybe it would be good to be able to get that information back. But then there's this level of stuff that probably the general population wouldn't even understand, some of this information that's coming back. I think there's a line. I wouldn't want all the information in the world about myself if it's not like... I don't know." 45:24 Athlete

During some discussions of biobanks, two scenarios were presented about how a person may be enrolled into the biobank. The first scenario was that an athlete enrolled in an HPR study and their samples and data from this study were shared with the biobank. The second scenario was that an athlete was having surgery or another clinical procedure, and the athlete's medical records and left over samples would be collected and used by the biobank. Most athletes reported being willing to allow for samples and data to be scavenged from clinical uses for biobanking research as that required minimal time and effort.

> "You wouldn't get anything. I mean, like I said for me personally, I would probably do it because it would help other researchers. And you are in that profile of the high athletes. So why not help their research to find out ways to improve performance? Because if they do find something and publish the study, you can benefit from that. You might not benefit directly when they're doing the research, but say they do find something that improves performance or injury, you can read all about the study and still help yourself in that way." 36:13 Athlete

However, one participant noted that the consent process for such sample obtainment should include explanations of the potential risk as most people would likely sign it without reading or understanding the possible impact participation may have on them (see the Research Impact Section for discussions on potential impacts of research and Consent Section for additional discussions related to consent).

> "I just view it as two different type of ... there are two different buckets, there are two different target markets. One is just passive. This is a person who doesn't want to lift their finger and come in, isn't that engaged. You're presenting them with an option that they can kind of all right, I helped someone I saw. They don't even

think about that now this is the bank. They don't read that part unless you're really hitting them in between the eyes. You're like, "You understand it's the bank, people can access this." Unless that's happening, which I doubt it is, I just think that's a different person versus the person that wants to go in and be a part of this and go through tests and get something out of it, they're going to want to understand it because that's the value that they probably get out of this is understanding how this works and learning from you and why you're testing this stuff, where it goes. They'll eventually understand what the bank is potentially, and that will be a little harder to stomach, I think." 26:70 Athlete and Non-Athlete Role

Commercialization

This study identified a propensity for athletes and non-athlete stakeholders to discuss athletes' *ownership* of their samples and data in a variety of ways.

> "It's not to say that they're not engaged because they're certainly, and certainly the ones who are at the reps at the union level and some are very engaged, but there's definitely this struggle right now over who owns the data, and you to understand where the concern comes from because there's a past there that led to some distrust." 18:11 Non-Athlete Role

Similar to the discussions above about college athletes' and their licensing agreement rights in the Athlete Characteristics Section (quote 18:18), one physician alluded to how the expansion of name, image, and likeness (NIL) licensing rights to college athletes may further contribute to an increased sense of ownership. Similarly, this participant discussed how a sense of ownership leads to questions about how future profits from commercialization of research impact altruism in research participation.

> "…probably even the collegiate, elite and professional realms, when you're talking about physically taking samples, then there's a lot of this, like not, intellectual property is not the right word, but like proprietary-... ownership. Ownership of the stuff, and I think a lot of that factors in of whether or not athletes want to participate into those kind of research.
>
> […] Because so, what is the reason behind saying like, okay, the Biobank is going to become the sole proprietor, the owner of all this stuff. And so, any research that comes out of it then assuming, because this kind of scenario would play into, I think this is the reason why people are worried about. Property and ownership. What if I give my sample, even though it's de-identifying and anonymous, but it's some cool new product or life saving whatever, comes from it and why would I not get credit or whatever, if there's this financial [profits]. Like why wouldn't they? And why does it have to be de-identified, anonymous, like give up all your rights to it? Like why does it have to be that way?
>
> […] So it's more about... I'm guessing that the sort of the nebulousness of like, "We're just, we're going to ask you to donate stuff for the greater good and if it helps everybody, great." And I

> think if the way it helps people didn't necessarily mean that the proprietor or whoever the person is creating, like all of a sudden makes gazillions of dollars, then there's less of this like inequity like, "Hey, that came from me. And they're now like bazillionaires, and I see none of it." If it is more like if it was created and it became, 'now we have a treatment that will prevent ACL injuries,' but people aren't profiting from it, they're actually making it available for everybody. […] That's where the altruism of research comes from." 8:2 & 8:42 Non-Athlete Role

In general, these discussions pointed to a growing perception that athletes are being more empowered to control and share in profits from activities that are affiliated with their data.

> "Just the increased awareness of self-advocacy and recognizing that the athlete identity is not the only identity at play has been part of an organization, I would say in terms of the athlete culture really leaning heavily into the why behind things and being able to engage in things that are more reciprocal than unilaterally. So that has been an increased trend in a direction of hope, just to care for athletes." 17:10 Non-Athlete Role

Beyond direct profit-sharing to individuals, the NFL's Player's Association was brought up several times as an example of how commercialized research can redirect profits back into a system that supports athletes. In this specific example, profits from the commercialization of biobank research using athletes' samples and data are returned to fund new and ongoing research efforts focused on improving the health of football players.

> "I've been […] overseeing health and safety and medical research in the NFL, NFLPA ecosystem. That includes the largest study of living former athletes in history and the Football Player Health Study, […] We understand longitudinal research takes some time, so we also had elements of that that looked at near term treatment interventions that we could commercialize. We've invested in I think about 24 of those to date, successfully commercialized three of those already, and others are still in the pipeline. […] we're investor in Dementia Discovery Fund, the Alzheimer's Drug Development Fund. And so a lot of experience from those two projects as well." 21:45 Non-Athlete Role

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> "PAs [players' associations] look after the player, and I think they have like the NFL PA would be a good one to approach. Smart, thoughtful people. They think strategically. They've done a lot of cool, interesting things. I think they have a [research] fund. There could be some sort of ancillary benefit to know what questions you're trying to answer." 26:52 Athlete and Non-Athlete Role

Several participants emphasized the gap in healthcare and research related to retired athletes, with many recommending the Alliance target recruitment to this cohort first to both bring the greatest benefits and establish trust amongst athletes (see Athlete Characteristics Section for related discussion). Many also discussed the need for the Alliance's research to be meaningful to either their community or underserved and/or marginalized communities (see Health Disparities Section for related discussion).

Another concern raised by multiple participants was the risk that research could be used for the development of gene-doping or other enhancement technologies.[2,92] Many participants focused on the competitive nature of sports and how that led to the traditional doping industry.

> "I mean, it was demonstrated by the use of steroids. Short-term thinkers, as long as I can make the team, earn a salary, get to my second contract, I'll do it. And of course we saw the outcome of that, and it's still being played out health-wise, and steroids obviously have had a terrible impact, but […] many athletes, tens and hundreds of millions of dollars. And so there was a risk rate, a reward benefit in their mind, and they're willing to do that. So if you can create knowledge about things that really do work, athletes would jump at it." 16:16 Athlete

Several participants extended this concept to question if HPR research would lead to new types of doping, such as gene-doping.

> "The only thing that ever that worries me is the gene technology that is taking place. You watch some of the Halo or some of the new shows that are on right now, but it seems we're really on the cusp of being able to use gene therapy and that type of stuff to further enhance the abilities of athletes, to enhance their performance, to make them bigger, stronger, faster, better like steroids did before. And if anybody thinks that there's not going to be some type of gene-enhancement therapy, that's going to go on

> to maximize performance for the short period, the window that you have to make enormous amounts of money, it's happening. And I don't even know how you test for that." 19:13 Athlete and Non-Athlete Role Role

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> "Aside from like the doping stuff, like that's just a very different sector and that's not what we're... Well, I don't know. I'm thinking of like how would we use like a biobank to potentially do research on potential methods of doping. […] It's like, oh, well now here is a kind of a questionable part of human performance, optimizing human performance, so we get into the world of doping and performance enhancing substances. But I would assume that if research in that realm involving the biobanking, it would be to hopefully try to detect and prevent and educate, that kind of stuff. So that's stuff that we would want to know." 8:3 Non-Athlete Role

As discussed in the Impact of the Research Section, some athletes occasionally couched willingness to participate in HPR in whether the research would impact their ability to compete from a doping perspective, particularly when discussing the regenerative medicine component. Similarly, in the Health Disparities Section several participants noted that if research innovations, such as regenerative medicine technologies, were to be commercialized, they would likely be too expensive for both the general public and most athletes.

Consent

Several participants spoke about the need for studies to collect the minimum necessary of samples and data and for all studies and consents to be hypothesis-driven, which is contrary to how biobanks operate. Most participants also emphasized the need for athletes to have risks and benefits of research participation clearly and specifically explained. For example, if there is a risk for the loss of confidentiality, participants reported that it is important to discuss how such a risk may directly impact them, like losing playing time or negative employment-related impacts if teams accessed their information. The quotes below are illustrative of the feedback received by multiple participants on these two themes.

> "How much of this information, what is the data that we actually need? I think a lot of people's first reactions in a lot of things is, "Oh, just throw it all in there." We don't need all that information. We're never going to use it all. It's all about [being] impactful. Some of it actually can cloud what we're trying to find. So, really being thoughtful and about what data points are actually needed and understanding how those exposures happen. So, in addition to FERPA, the universities also have to deal with public records requests. So, understanding what data could be exposed and how they may be identified, and walking it backwards to pull that string of that sweater to look at side by side, what information do we need? What do we really need? And then what is the riskiest information? And then how do we marry that? [...]
>
> And walking people through how information is de-identified as well as it's not perfect. There may be some risk because you're a big shot […] that somebody could connect the dots and figure out it's you. And if that risk is too much, then you shouldn't do it. But I think the risk is low and we do everything we can to mitigate that risk. And walking through people and having that understanding of what you do, pulling the curtain back has been the most helpful [...] You can have a meaningful conversation about looking at what data points are and aren't used and aren't disclosed" 41:20 Non-Athlete Role
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> ~
>
> "And so, we talk to a player about, "Hey, we're thinking about this, there's a specific hypothesis to this is what we're looking for. We

> may want to see if you have low methylation of testosterone." There's a hypothesis to it, and we know exactly what we're looking for. It's not, "We want to open up your entire Pandora's box to figure it out." […] This is why we're looking at it to fill this gap. It's not to look at every single pinky toe strength you have […] but the main ones that we think will limit you potentially from reaching your greatest potential. And so, I think there's a lot of positive there." 11:26 Non-Athlete Role

As previously discussed in the Impact of the Research Section, the competitive nature of the sports, several participants reported that participation in research may be motivated by altruism, but the participants may be harming the longevity of their careers if the research ends up helping the younger competition more than the participants, which is unique to elite athletes and extended to every skill level. As previously discussed in the Impact of the Research Section and Confidentiality Section respectively, other examples raised were that research discoveries may change the way in which the sports industry identifies elite athletes and that results of the research may negatively alter public perceptions of athletes. These risks are typically classified as 'unknown risks' in consent forms. However, several athletes stated that they would likely not have understood the potential ramifications research participation may have for them personally or professionally during their college years. Several participants indicated that only older, more seasoned athletes would be able to identify these more ambiguous risks for themselves, with high grossing professionals receiving advise from agents and/or players' associations (see the Athlete Characteristics Section). The quote below discusses how these 'unknown risks' may manifest and that younger athletes may not yet realize that sharing their information could hurt their careers in the long run. This quote also describes how younger athletes would benefit from having a seasoned athlete available to talk to about potential future risks of research participation.

> "I am speaking again from the part where I can look back and I can understand things much better, which obviously, we always do

> that. Hindsight is 2020. Basically, the only thing I would change now is if I had a niece, nephew, a good friend, a son, anything, I would probably push more my perspective and guide them through it. That would give him a little bit advantage.
>
> […] I do think that college kids are probably the best target again, because […] they're more willing. I would just say the best thing you can do is explain to them, be like, "Look, this is what we're doing. We're going to expose this information to the world, and your name might not be attached, but your product will be." So again, I don't even think that's a bad thing. I encourage competition. […] Again, it really takes the next guy five years for me to go into the research, to apply it to himself, to then get better, which is all great and amazing, especially in the competitive sports world." 39:24 Athlete

Another athlete recalled there being an option to participate in a biobank during their routine drug screening. The first time they saw this short consent, there was not enough information or anyone to whom they could ask questions. They reported that they did not sign up until they were able to speak with someone about the details. Here they reflect on that experience.

> "I think back to that moment [when offered to enroll in the anti-doping agency's biobank], when you don't really know what's going on, and it's just presented to you, and you're supposed to decide in that moment, I think there's some discomfort in that." 45:26 Athlete

Overall, most participants endorsed providing athletes with more autonomy regarding what samples and data are collected and how their samples and data would be used and shared. Many participants suggested offering athletes a 'menu' of options that allowed athletes to choose what types of data and samples they consented to share. In the menu of options, each dataset and sample type would include a scientific justification for why this data/sample is needed, how it would be used, and what research questions it could answer.

> "Does that mean they're going to give up a hair sample? They're going to give up a skin sample? They're going to give up a muscle sample...Clearly [explain] what they're going to be giving up and

> why they're going to be giving this up. I think as long as that's very clearly outlined, and then honestly, I feel like giving them options. Maybe they want to give two of the three, instead of saying, "We need all of these things." Give them a way that they can still participate, but it may not necessarily be 100% of what you want, but it gives you 80% which is still hopefully worthwhile. So if it's spit, this could be the blood…So if we can give them an opportunity, there's 10 different things that they can…How many are there that they could possibly give up and is this pertaining to one single study or is it these 10 samples will be a part of a hundred studies?...
>
> I think more guys would be interested in…being involved with the study and having it clearly outlined what that study entails. 'It's about muscle generation,' or these guys, when it comes to cartilage loss, ligament tears and things like that, that's something that resonates with them, but I think also giving them an idea that there's a much greater bandwidth that this is going to impact" 9:13 & 9:16 Non-Athlete Role

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> "…where it's like a two-part consent. I think that's the best way to go. One is, I know exactly what this is going to be used for. Part two, any other use will be completely de-identified, aggregated data, no chance of discovering I participated. And make it a two stepper so that somebody can have that flexibility. I think that is probably the best we can do." 21:55 Non-Athlete Role

Regarding the biobank specifically, a number of athletes reported interest in learning about and often approving what other types of research their samples and data would be used for.

> "… probably the athlete should be the one, I think, in control of the information. […] especially with the leagues and especially the women's soccer league and where it's developing and it's new. And I think that I would want the athlete to be in control of their information for sure. And decide who does or doesn't have access to information. I think, in any kind of especially with mental health stuff, if I guess the athlete is at risk of self harm and something very serious, then there's a little bit you can sometimes- go around getting their permission to give stuff, to talk to physician. But in general, I think, it should always be like, "Okay, do you want the team physician to be involved in this? Can they help you?" And I think most of the time athletes and people are pretty responsive to things, but I think, athlete directed would be the most important thing." 30:57 Athlete and Non-Athlete Role

Many athletes advocated for individual consent for all secondary research uses, while others only required additional consent for sensitive data, such as menstrual cycles, mental health, and genetic information.

> "…take for [example] genetic [information], there were a lot of athlete genetic tests rolling around in the past five years. Certainly, [I] have my DNA floating out there in the ether, but you didn't really know at the time that […] these companies were probably just collecting data really. That was probably their business. Since you're doing a [research] study, you're informed that's [collecting data is] your business. That's going to make it harder. So, I think there will be a small segment of any population that is super risk tolerant, finds value in participating in a study, especially the scope and breadth that you guys are trying to do and wants to advance science, humankind, whatever. But it's a much smaller population than a targeted, specific thing that they can wrap their heads around. […] They'll [athletes will] eventually understand what the bank is potentially, and that will be a little harder to stomach, I think." 26:5 Athlete and Non-Athlete Role

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> "I wouldn't be super concerned about necessarily knowing that my data and information was used, but I don't know how I feel about my DNA just being used in a study that I don't necessarily know about, or that I don't know what's being used for at all. That seems kind of sketchy…
>
> [Asked if being notified about research using DNA would improve comfort] I think that would help, but I think I would still want to be able to have the option to opt out or in.
>
> [Asked if committee of athletes sufficient for deciding if DNA use is acceptable] I think would want to be the one, and maybe something that could be done that is at the outset. If you could say, these are the kinds of things I'm okay with, versus, these are the kinds of things I'm not okay with. Make some choices about the general types of research you're okay with your information being used for versus not, or contact me if you are going to do this. Just something at the outset that's a little bit more specific." 46:17 Athlete

This participant points to the GDPR that requires consent for all future uses of samples and data as a model that should be considered despite the risk that less secondary research will be conducted.

> "It's the open-ended, forward looking nature of it that I have the most problem with. And I feel like, especially if this is going to be an international effort, I can almost guarantee unless there's an aspect of the law that I haven't read yet, you're going to start running into trouble with stuff like that in the EU.
>
> Because they're going to say every time you share it outward again, there needs to be a new consent. And I think that's probably the way to go, frankly. I realize that it will make the data much, much less useful because if second level or tertiary level study acts like, "Oh, we want to use your bio-bank book." [and] "Okay, well, we'll let you know when we've sent out the however many hundred or thousand explanatory, your consent is required for this new study." Maybe, maybe not. I would hope that would go okay." 29:27 Non-Athlete Role

As discussed in the Return of Results Section above, some researchers, on the other hand, spoke about the logistical issues related to deviating from broad consent for secondary research uses and trying to implement study-level consents. Specifically, the amount of time and labor to manage both consent and returning results may be too difficult to warrant the possible increase in participation rates (see quotes 10:13 & 10:31).

The consent process itself was also discussed by several participants. Athletes were mixed as to whether they would make the decision to participate in research by themselves or whether they would consult with one or more trusted advisors, including family, friends, former medical staff.

> "I probably wouldn't talk to anybody about it [research participation]. I probably wouldn't." 22:45 Athlete

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> "I think I would just make the decision myself if it was up to me [and not prohibitted by their contract]." 34:16 Athlete

~

> “I probably would've just made the decision myself, I think. I usually am like pretty trusting and I always sign up for survey.” 30:61 Athlete

Many athletes spoke about the need to engage with a wide variety of trusted advisors during the consent process.

> “I might talk to other players, for sure. If I saw benefit, that, sometimes you see their benefit. You know, it's a small little community that does share information.” 16:40 Athlete

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> “No, I think it's definitely important, similar what you're doing. You're hearing different voices and different perspective on things. I think it'd be important to at least get three different perspectives. I say three because there's always three sides to a story, their side, your side, and then the truth. So if I could get three different sides, I have some unique perspectives.
>
> I'd probably go from my agent, who is loyal to his clients, not the game because he benefits if I benefit. I would talk to my wife because I spend the most time and she is the closest person to me. Then I would either juggle between a close friend in the same situation as me or a prior coach, not a current coach, that I believe had the best interest for me as well.” 39:26 Athlete

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> “A trainer, a coach, family, but specifically trainer and coach are high on the list because they see you perform your sport probably on day in and day out if not weekly. So it's something that they would want to be a part of.” 40:1 Athlete

Similarly, many participants indicated that athletes, particularly while in college, may be easily coerced into research participation if advised to do so by an authority figure, such as team staff.

> "I would be hesitant to have people like coaches involved. People who are in more of a decision making capacity to hold an athlete back or let them play or let them practice like who has that power over the athlete. So I think that maybe extends beyond coaches and

> it goes to parents and administrators and other folks."14:5 Non-Athlete Role

Several athletes spoke about measurement during college performance but did not report having been involved in research studies prior to this interview despite most having attended and played for major universities. Of the 20 professional athletes, 8 (40%) were either 'not sure' or denied previous research participation. This lack of awareness of research in college was likely related to collegiate athletes being required to consent to research using their health and sports performance information during their on-boarding process. As one medical professional and researcher noted that the form was included in the copious amounts of onboarding paperwork.

> "If it is data that we are actively collecting, they are informed about it because they have to sign a consent. But sometimes if it's like past data, de-identified, they're not necessarily aware of it, but that's also because when they come on and they're competing for the school, one of the many forms they sign is the form that says, "We may use your data for research."" 8:34 Non-Athlete Role

Similarly, the process for obtaining consent varied across skill levels. Most athletes reported that they would have participated in a research study as a child simply if their parents told them to.

> "I'm trying to think, when I'm a kid and my parents told me to do it, I would probably be like, "Okay, whatever." I probably, like, would have no opinion on it. [...] You're just doing what you're told." 33:18 Athlete and Non-Athlete Role

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> "I can imagine the younger version of me asking my parents, "Should I do this?" I feel like I ask them all the time, "Should I do anything?" I was always searching for the right answer." 45:25 Athlete

Several athletes reported 'going along with the team' as why they previously participated in research studies.

> "I think in general you were probably allowed to opt out of whatever, but I don't think anybody opted out of anything that I remember, from either the national team or the college stuff." 30:37 Athlete

Similar to team athletes' concerns about the league having access to their data (discussed in the Confidentiality and Discrimination Section) or being in discussions about designing the research (see the Engagement Section below), several participants felt that recruitment should start with the players' associations.

> "But in the end, this is about individuals. If you go in the other direction, through the leagues and then try to get to the players, if it works, it would be an act of something outside of this world." 11:29 Non-Athlete Role

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> "I'm thinking, the player's association has this thing for incoming player rookies and stuff like that, where they're mandated to go through […] And if it was something where you could get involved with NFLPA, then it would be part of the rookies mandated like courses in which they would have to participate in. And then that information would be there to follow them through their career, potentially. And you could analyze it as they go out, year to year potentially." 22:55 Athlete

To this end, most participants from team sports encouraged letting players' associations to lead recruitment efforts (see the Engagement Section below for more information).

Engagement

As previously mentioned, sensitivity of mental health, genetic data (Confidentiality and Discrimination Section), transgender, and menstrual data (Disparities Section) and athletes' desire to restrict and/or control data and sample access and uses (Confidentiality and Discrimination Section and Consent Section) were recurrent themes. As discussed in the Return of Results (quotes 26:27 and 33:6) and Consent (quote 26:5) sections, most participants expressed that athletes would have a strong interest in knowing and controlling to some degree, as some limited control to sensitive information only, how their samples and information were being used. There was also a general interest in receiving individual- and study-level results, with some suggesting that giving prioritized access to study-level results may be an incentive for participation (see Return of Results Section). As there are many potential policy and study design implications for researchers to consider, this study also endeavored to explore how the various stakeholders would like to be engaged in discussions about how research studies were designed and implemented. This discussion was facilitated by asking participants which stakeholders should be "at the table" as part of the decision-making process.

Generally, athletes believed that scientific concerns would be the same for all athletes, although exceptions such as scientific inquiry with transgender athletes were identified.

> "Well, to me, it's the same thing. A kid achieving a dream, whatever it may be. It's not about the money, that separates it from us. Kids that go from high school to college, they just want to play at that level be able get have a chance to get a free education. That's they're doing it for. And the same thing to me from college to pros is, does it affect your ability to do what you say you want to do? Will it stop you from achieving your dream? Those dreams may change, but I think it doesn't change for me personally, from high school to college. It may change for other people because dollar signs are behind it. And there may be money at risk, but for me, it really doesn't." 32:2 Non-Athlete Role

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> "And so if you have like an amateur or a collegiate athlete or a minor league […] that's considering research, I don't necessarily think they need to have any different concerns because the same things about property and effect on performance would still in theory apply." 8:20 Non-Athlete Role

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> [Discussing high risk injury result being given to athletes] "I think once you get into the mind negatively of an athlete, they can't compete. If you're not in that right mindset, you're not going to win. And I think that that's true of team and individual players." 38:23 Athlete

However, as discussed in the Confidentiality and Discrimination Section, the risks for discrimination were perceived as very low amongst individual sports and very high for high-grossing team sports. In general, participants felt that protections for those most vulnerable to discrimination (athletes in high-grossing, team-sports) were appropriate to have in place for all participants.

> "I'm also an individual tennis player. So, that is what would drive me at the end of the day to have that individual approach. […] But let's say if you're on a football team, basketball, baseball, any other kind of team […] having that knowledge out there publicly can affect your career. […] That information, it could be good or it could be bad. […] But as far as having that knowledge out there for different sports atmosphere might be a little bit detrimental to yourself because you're playing a lot of sports. You're playing under a contract. So, if someone sees a weakness or a flaw or something, then you're liable to get cut. In tennis, no one cares. […] I've got a little bit of unique perspective, being a tennis player, a little bit of an individual mindset, more than the collective good. But yeah, things like that wouldn't necessarily affect me and my sport, but I can totally see how that might be good or bad and different [across sports]." 44:8 Athlete

Decision-Making

A recurrent theme across many of the prior sections is the need to engage a diverse group of stakeholders, particularly athletes, in a process that empowers athletes to participate in the

decision-making process for research design, practices, and policies. Most participants prioritized athletes as the main stakeholders in the decision-making process.

> "I think in an ideal world, if some control, I guess, were to be given to the actual participants themselves, that would be worth a discussion, I guess, in some ways and logistical challenges aside." 8:19 Non-Athlete Role

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> "So, I think the actual organizations that are supporting these athletes shouldn't necessarily be too involved, but I do think working with the actual athletes about what they care about […] So I think the athletes are number one, the people that should be engaged in this." 20:50 Non-Athlete Role

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> "I think an athlete definitely should be there [at the decision-making table]. Athletes only see what's happening right now. I think you have a retired athlete that may need to be there, because they see exactly what's experiencing after the fact." 32:68 Non-Athlete Role

The need for promoting athletes' autonomy and agency was also common across most stakeholder types.

> "…there has been such a huge movement in the trend of, at the agency, or sense of agency. That's just something to be mindful of." 17:19 Non-Athlete Role

Similarly, athletes themselves usually expressed the desire to be the ultimate decision-maker regarding how their samples and health information are used (see the Consent Section for more discussion). However, athletes were divided about whether it was appropriate for other athletes to act as delegates in the form of a Community Advisory Board for the decision-making process.

> "Are you talking about this in terms of representation? Like these people represent me and speak for my interests? Because I wouldn't want anyone else to do that other than me." 34:30 Athlete

Whereas other athletes reported being comfortable with delegating decision-making to a proxy. Similarly, several felt that retired athletes would be equally good at representing athletes as active athletes.

> "I think it'd [having retired or active athletes making decisions would] be equally beneficial I think. They've been through it, that you can trust their experiences. And I think if they've been through it too, it's just as beneficial. Maybe you're too busy and you're like, "Okay. Yeah, that person can speak on what they've seen and what they've done and what they've experienced." They're just as good as your own." 36:5 Athletes

Athletes were reported to be the primary stakeholders who should decide questions about data and sample access (see Confidentiality and Discrimination and Return of Results sections for discussion), meaningful benefits to participants and the community (see Health Disparities, Return of Results, and Commercialization sections for additional discussion), methods for obtaining consent (see Consent section for examples), and defining the appropriateness of policies and protections within the research process. Most participants felt that all athletes, team/individual and men's/women's sports, should all be able to work together to inform the research process.

> "I really feel like it would be helpful to have everyone [team and individual sports players] at the same table and sharing that information so that getting to share ideas. Maybe it does work for one group and it doesn't work for the other group. And if they're all there at the table, they can talk about it and discuss, maybe we need a different set of rules for this type of athlete versus the other type of athlete." 46:27 Athlete

Many athletes believed other non-athlete stakeholders should serve in supportive roles during the discussions of how research studies and practices are designed and implemented.

> "I think each sport is different and has a different culture. […] Certainly, there are legal and ethical implications of all this. I think an important person would be someone that's involved in data security. […] Obviously, you're going to have research scientists

> and the people that are actually going to try to answer some of these questions." 26:68 Athlete and Non-Athlete Role
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> "I believe having an agent or manager that has your best interest [in mind], and they might think of something else that's good or bad. But I think that's good." 28:41 Athlete
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> ~
>
> "It's definitely the medical staff and probably more so than the team doctor is really the team trainer and the most teams have a sports performance coach too. […] But they're the ones that are usually[…] implementing whatever or analyzing the data themselves. I definitely think them and the coach too. I mean, the coach is going to be really key about how they wanted to integrate into their everyday practices and stuff like that too." 30:65 Athlete and Non-Athlete Role
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>
> "…overall, the ultimate say would be the athlete themselves because it's them performing." 40:18 Athlete
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> ~
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> "I think there has to be a rigorous oversight panel that would include players and scientists. Somebody that has clinical knowledge about a disease state when a company or an organization comes forward and says, "We want to dip into these samples for this, this, and this." It has to be a compelling reason. It has to be an unmet need. There's got to be reason those samples are valuable. They're rare. They're not in huge supply. So you've got to be discerning about who you give it to." 16:8 Athlete

Players' associations were consistently identified as critical stakeholders for team-sport athletes, particularly from high grossing sports.

> "The players association is your number one target. So the players, they don't all love their players association, but it's what they have. And they feel that the players association for the professionals is on their side." 10:15 Non-Athlete Role
>
> ~

> "I would go through the unions. The players will be suspicious of the leagues and teams. They worry about those sources exploiting their data, so I would try to stay on the player side. We'll have less controversy, and you'll be viewed more positively than if you go through the leagues or the teams." 12:9 Non-Athlete Role

In discussions about the role teams or leagues should play, participants associated with high-grossing team sports consistently advised that players' associations should be the ones determining when and how teams or leagues should be involved. Furthermore, it was frequently pointed out that the players' associations should always be at the table when the Alliance is working with teams or leagues if for no other reason than to maintain trust with athletes.

> "You certainly should not have the league. They should not be. Stay far away from management and leagues. […] I just think if it's league involvement, unless the league and the PA [players' association] joint participate in this, then it seems like there's a nefarious reason for collecting all this data." 26:72 Athlete and Non-Athlete Role

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> "I would involve the league and the players' association. That's where it would start for me. The league will understand, not all but most of the team's concerns. If it's a league and players' association-driven initiative, I think it's got some real legs." 7:46 Non-Athlete Role

Participants, including the agents themselves, generally did not feel agents needed to be a part of the decision-making process with the Alliance.

> "I don't know that you could get one [agent] to be at that table unless there was something in it for ... there's a lot of risk for them being at the table with that going wrong. Yeah. Or at least zero benefit…" 26:47 Athlete and Non-Athlete Role

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> "I probably wouldn't [involve my agent with HPR]. Yeah. Well, he's basically just there to present contracts to me. He doesn't really serve any other purpose, besides the median between me and the club." 45:27 Athlete

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> "I actually would not involve their agents because their agents like in some ways, they have a totally different, I guess, skin-in-the-game when it comes to the athlete themselves. It's representation, but sometimes there's financial game that's not related to the health and wellbeing of the athlete in general. I suppose like the athlete would be an important person to involve, I suppose." 8:15 Non-Athlete Role

When one agent was asked if they felt agents should be involved in decision-making process, they simply responded as follows:

> " I don't know about that." 25:35 Non-Athlete Role

Although, participants recognized the need for agents to be informed about the research more broadly to improve buy-in and facilitate player participation.

> "I think agents, if you're able to have them on board would be super helpful in committing a player to doing it and having them say, "Hey, there's a lot of valuable information you're going to get at the end of this. And it could be helpful for your career and maybe lengthening your career or understanding yourself better."" 35:36 Athlete

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> "In our sport, you will need to take the large baseball agents with you to have the participation of their players. […] they're [the athletes are] going to trust that person as much as almost anyone. […] they're [the agents are] going to need to be either have seats at the table or separate meetings explaining why this is very important. […] If you get a player agent who says, "Hey, I think this is, it's harmless, it's safe. You're doing something to allow for science to really understand what creates human performance and elite human performance." I think you got a chance to get some data, get some information." 7:27 Non-Athlete Role

Furthermore, training staff was frequently identified as an important stakeholder group who would be trusted to provide education related to research participation, but research recruitment should not utilize team staff (see Section 9 for additional discussion regarding the consent process).

> "Probably athletic trainers as well and maybe physical therapists. Athletic trainers are really the bridge between the health side and the players side. They often spend a lot of time with the players. Having their input would be very helpful." 6:15 Non-Athlete Role

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> "Obviously, trainers are your best friend, they could be super helpful, but they're also going back and reporting to the scouting staff and the owner and the coaches, information about your value to the team from a health standpoint." 35:37 Athlete

Several team staff members of lucrative professional sports explained that their teams found it necessary to make athletes partners in research initiatives in order to build trust. They emphasized the importance of bringing athletes along by being up-front about why something new was being suggested, like wearable technology, what they hoped to gain, how the information would and would not be used with well-defined limits to future use restrictions.

> "The tracking of player information is a big question mark. […] We want to train players to get them better at baseball, so we put a sensor on the bottom of their bat, and we do it all day for our minor league players. It's a great way for us to help train the things we're looking for in a baseball swing. MLB had to negotiate with the players union, the players' association at the major league level and said, "Okay, this is why the teams are doing it. This is the data they're gathering." We [the team staff] need to go, the same way you're getting my consent, we need to get the consent of the Major League Baseball player to put this sensor on his bat. We need to tell him how we're going to use the data, who the data's going to, things like that. Because there's a, I don't want to say a fear, but there's a question mark on, "Hey, they're going to use this in some kind of weird way."" 7:7 Non-Athlete Role

This performance team staff built on the previous historical context and compared the way sensors have been used more broadly to medical data while contrasting the level of security for the different information.

> "I think that MLB particularly got off on a very bad foot related to integrating science into sports because it was used in a negative light and kept from players. […] This wasn't a great place to start with sneaking behind people's back to help science, right? It was

> almost got viewed as another way to do medical [exams]. But, at least with the medical [exam], you get a medical record that you can track and keep up to date. And some of the scientific work, and it's on a Cloud somewhere, it's held into someone's Excel spreadsheet on their computer or whatever it would be. So, it just wasn't really transparent." 11:3 Non-Athlete Role

This participant went on to describe how that historical context has led to Major League Baseball now treating athletes more like partners than research subjects.

> "… we've tried to build communication with the players first, that we hope builds into a relationship. And, that communication is only strong as the reliable and valid information that we have to support that discussion. […] How is this beneficial? And, why are doing this? And, why are we doing strength conditioning? And, why are we doing preventive care? What's the reason for it. And, if it's not to make them better, why should they care, right? And so, I think we've tried to adapt a very player-centric model because that's who we're here to serve, the players, the coaches, and by which we serve the organization to a much higher level." 11:3 Non-Athlete Role

Finally, this participant shared an example of how the athletes' are empowered to decide for themselves whether they want to participate in more experimental practices.

> "[…] from a player specific standpoint, I think understanding the why, and also giving them like the autonomy of, "Hey, listen, if we don't get this, it's not a problem, but we'll just have to guess more. And, we'll do our best job at guessing. But we'll do our best job at subjectively doing something to fill this objective gap, but it's going to be our best guess. And so, if you're okay with that, it's not a problem, but we want to be transparent with you about how we can best serve you, right, in this capacity."" 11:3 Non-Athlete Role

Athletes, agents, mental health practitioners, and players' association representatives advised that the most important characteristic of supportive stakeholders is that they are trusted.

> "It's not so much a classification of which silo you want, whether it's coaches or doctors or athletes or whatever, it's who you get. Because there's good and bad in every aspect of life. The bad will find you. Your challenge is to find the good and so you need to find the right coaches. You need to find the right doctors. You need to find the right athletes. You need to find the right scientists. There's a ton of good out there, but it's hard to find." 5:25 Athlete

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> "Obviously, within the elite athlete community, which I'm sure you are well aware, trust is a big thing because everybody who is on the outside of that circle is trying to get something from them, and even some people that are on the inside of that circle. […] I think in order to make it a palatable process for the athlete, I think the most important thing is having individuals that they trust to help them with decision making and help them with the implications of what they're working on. I think the most important thing is trust." 47:23 Non-Athlete Role

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> "You know, just the people that the athlete trusts whether that's their significant other, their parents, whoever is their circle of trust. You'd want them involved in it as well." 15:14 Athlete and Non-Athlete Role

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> "I think it needs to be smart men and women who have shown unusually strong character and have a history that proves that they care about people, the human race." 25:56 Non-Athlete Role

For example, several participants indicated that it would be helpful for them to have medical staff present to help translate how the proposed research may impact their health and the generalizability of the proposed research.

> "You need somebody else that actually looked out for these guys [professional athletes], that truly care beyond their... […] I think that you need whoever's on the other side, truly explaining what happens, from point A to point Z, so people have a thorough understanding of really what they're getting themselves into. And I think that, if it gets to a point where an athlete or the player's side and they want to have a doctor that can tell them what the repercussions are from their side, of giving this up, what happens to them, whether or not it's really, affecting or impacting anything for them later on down the line, not only today, but later on and what happens. So, I think they would need medical opinion on their side. Just like you guys would have medical opinions on your side, so to counter. So they feel more comfortable.
>
> [Asked if the medical opinion for athletes would be the team doctor]

<Bellowing laughter>

I mean, that's a good spot to start. I mean, there are some good team doctors, I'll be honest with you. There are some really good team doctors…But once they become and they see them in the light of the team, some doctors are sitting over there and they're strong enough to step out and say, "Hey, this isn't best for the kids." Some doctors just go along with the team, playing and what they're doing. So, not all team doctors are bad." 32:35 Non-Athlete Role

Most athletes, agents, mental health practitioners, and players' association representatives were also generally opposed to the suggestion of using team physicians to fill this role. As discussed in the Athlete Characteristics Section, athletes have seen team physicians who testify against athletes leading to team physicians being not trustworthy advocates for athletes (21:74). Similarly, other stakeholders with any perceived conflicts of interests were generally distrusted, although exceptions could be identified.

"There's probably a conflict of interest everywhere to some degree." 18:21 Non-Athlete Role

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"Coaches, I'm kind of like from my personal experience, I know they want the best for the student, but I know many coaches that kind of milk it and take advantage of the athlete because of the monetary value behind it. And I'm like, "Dang. That's unfortunate," but I guess that's part of business." 23:26 Athlete

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"…the Players Association is worried about the Players Association, first and foremost. Then they worry about the player, if it doesn't put them in a bad spot. So, […] they wanted to pass a new CBA [Collective Bargaining Agreement] because it keeps them in office. New CBA keeps that the new director in office, keeps the guys that are working for the director, keeps them there and solidifies their future. It's inevitable. It's hard for them not to put themselves first in their job and their own status and security, before they put anything else. So, I think that they try, but I think there are too many shortcomings that they get caught up and they get caught up in precedent." 32:19 Non-Athlete Role

Despite many participants noting that conflicts of interest abound in professional sports, individuals and groups who could be trusted were still frequently identified.

> "…if I had a private trainer, […] They're there and they're paid by you, they're motivated to have you as a client, so they would definitely be another one who's on the players' side of the wall. They would probably be the most knowledgeable on the information that was being provided." 35:39 Athlete

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> "I'd probably go from my agent, who is loyal to his clients, not the game because he benefits if I benefit." 39:26 Athlete

While several athletes reported that they personally wanted to make all decisions about how their samples and data are used, stakeholders who were physicians, researchers, and team staff frequently proposed a more top-down decision-making model. However, notably team staff were acutely aware of the distrust that existed between athletes and team-driven initiatives, and although they promoted a top-down decision-making model that emphasized team and league management working directly with the researchers, they advocated for players' associations to be active participants for all discussions.

> "The league wants the best and healthiest players. The players association wants the best and healthiest players. Things that would promote or lead to that kind of end goal should be areas that the league and players association can get on the same page. That's who I'd have at the table. I mean, there are people, there are doctors, there are physicians at the tops of both those organizations. I would start there with this is our goal." 7:20 Non-Athlete Role

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> "I would start with our [team's] ownership. Well, I'd start with us, like us internally like our medical staff." 9:23 Non-Athlete Role

Physicians and researchers spoke less frequently about conflicts of interest between themselves and the athletes and often cited team medical staff as playing important roles in deciding how the research should be designed and conducted.

> "...athletes' health and wellness is often controlled by the performance coach or the strength performance coach. […] I think those people actually, are really important […] And then of course, team physicians or chief medical officers, people that are in charge of the medical side, that's another big group that should and would be at the table." 13:5 Non-Athlete Role

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> "Probably athletic trainers as well and maybe physical therapists. Athletic trainers are really the bridge between the health side and the players side. […] Certainly hearing directly from athletes would be very helpful. [...] There may be some discussions as well with sports leagues. I don't know, leadership or legal as well. […] The other thing that comes up is for most professional sports league, there's a union. Usually for any bigger project, if it was something that would go out to the whole player group, it would need to be approved by the union." 6:15 Non-Athlete Role

It was also discussed that women athletes need to be equal partners in the decision-making process. Most participants hoped that historically underrepresented groups, like women, would be valued and appreciated, many also acknowledged that in practice there may need to be additional measures taken to break the current cycle of prioritization.

> "I think there's the most space now and the most need right now [to give women a seat at the table]." 22:58 Athlete

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> "I hope so [that women athletes could be equally heard at the table]. I mean, yeah, that's a no-brainer. […] I think women's sports are just as important […] as men's sports are from grassroots, from under eights, and under tens, to region all the way to Olympics." 28:50 Athlete

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> "So one, is very specifically for men and women's sports. And then because I'm in the soccer world hearing so much about that, making sure it's equitable and whatever is being done, both for opportunities, but also for protection of whatever needs to be protected, right? So, it's not being treated differently. It's not males are being escalated in terms of what we're doing for them or what information is provided to them. It's very much an equitable thing. I think that is important both, again, in terms of what's being done and also information offered and if there's any stipend, reimbursement, whatever you want to say that, again, that is also equal to the athletes." 13:11 Non-Athlete Role

Despite desires for men's and women's sports to have equally strong representation, the participants were mixed about whether women's sports could be heard, so to speak, if at the same table as high-grossing men's sports.

> "I do think the higher visibility sports and sports that do bring in and generate a lot more money probably are just inherently a little bit different, or at least, at the end of the day, money will be involved somehow, some way. So, yeah, I think that's where as a research group and as part of this project, it's almost because of that, there has to be more attention and more efforts given to those groups and those sports and those classes that just don't have that access because they're not those sports that we traditionally think about." 13:49 Non-Athlete Role

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> "…some [athletes] may get the higher bucks and more attention on them because they bring in more money…" 36:28 Athlete

Similarly, participants identified research interests would not always be universal between the sexes, and there may be other subgroups that should meet independently to identify their unique priorities.

> "I think there are different tables. I think there are times it's very important to have them at the same table. […] certainly with US soccer, where we know that the women have more of a presence. They're more successful. They get more attention. Bringing them at the same table sometimes can be really helpful. Then there are other times where guys still are uncomfortable with certain topics, so we can separate it, so we can do both. We can have them separate and bring them together because we never wanted to feel

> like a varsity and a JV. Sometimes it's the same issues. And sometimes it's separate." 20:37 Non-Athlete Role

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> "Yeah, I think I would say that it would be great to do it separately and I don't know if it was already planned on that to identify females versus males, but I think male and female bodies perform differently. So whether or not, I don't know how the research would be doing it, but I think it's to identify one gender would be really beneficial because of how we're just built different." 40:8 Athlete

However, there was frequently a tension around what meeting separately may imply and a fear that separation may result in less funding or emphasis for women's sports due to that historical legacy. Ultimately, most participants emphasized engagement activities that balanced meetings with the entire group and meetings with individual subgroups to ensure subgroup-specific requirements are captured and incorporated into Alliance policies. This participant weighs the benefits of having various groups all together against reasons for why targeting specific groups separately may be beneficial as well.

> "I feel like in some cases there's a benefit to attacking everything at once, but in this case, I do think, you're probably able to spin a lot more upside to female athletes because of lesser research and because the requirement to prove using data, your abilities and strengths and capabilities for women is required and almost never is for men. […] So, there might be more people within that group [women's sports] that feel there's a higher upside. And then if you attack them independently, their natural inclination will be to see the upside. Whereas if you have them alongside a group that is used to getting everything they want without having to ask, they [men's sports] might poison the well, because of their doubts, because they don't need it as much. Right? They believe that probably there's already enough money and research and time being spent on them. There's always the risk though when you siphon off women, that they believe that they've been […] separated because of intention to invest less or to do less, right?" 31:59 Non-Athlete Role

However, many participants voiced support for having a hybrid-model of engagement where everyone meets together and, when appropriate, smaller groups meet independently and report back to the larger group.

> "I think you could do either separate or maybe hybrid. But yeah, I definitely think there's differences when it comes to the men and women, different aspects they can help more so with women and then men maybe don't need them as much. But yeah, I think maybe a separate or a hybrid for that person to choose like, "Oh yeah, I'll be in a room with men." Great. But if a women's like, "No, no I want it to be just women," I think it would be beneficial to have a combo of both. There's just differences that maybe they're not comfortable with talking about." 36:21 Athlete

Communication

Several participants spoke about how distrust in science is common amongst athletes, as with the general public, and this was another reason why transparency and clear communication would be critical for both recruitment and the general sustainability of this research initiative.

> "It's [research is] not unlike, honestly, a lot of the discussions we've had with just COVID protocols, vaccinations, things like that. […] I'd say, there's just not a lot of trust in science in locker rooms. It's certainly, I don't think, ignorance or anything like that. It's just that that's not the environment that people grew up in. I'm using broad, broad generalizations. This is not for every professional athlete. But I think those are some of the challenges. If you ask to take something from a professional athlete, they're going to say, "What's in it for me?" I think that's always a question researchers... I have to answer that when we ask for their time or for them to be Guinea pigs in some kind of thing that we're working on, I have to answer that question all the time." 7:17 Non-Athlete Role

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> "I remember the first time I got drug tested and there was a question on there do you want your sample anonymously be contributed to? I don't remember what it was for, but I remember reading that and like, "What is this?" I've done them before and it wasn't on there, and then all of a sudden it was on there. The doping control person, […] she was like, "It's just totally your choice. You don't have to check yes." I remember thinking I felt

> guilty for not checking yes, because I felt like I wanted to. But I was like, "I don't know if I believe them." The first time because I think I checked no. Then I went and asked, I was like, "Can you explain what this is?" Once I got more information on what they were doing, I think I checked 'yes' every time after that." 45:26 Athlete

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> "Well, I think that certain people, whether they're an athlete or not, there's a little bit of skepticism around some research and some people just have a hesitancy to partake because of any risks that may be inherent or just any impacts on them or their career. But again, I think transparency of information from a researcher's standpoint, and again, drawing on most athletes' desire to be philanthropic and wanting to perform their own, or improve their own ability to do their job, I think when that's presented well, I think most of those hurdles could be overcome." 47:18 Non-Athlete Role

Most athletes reported an interest in or expectation for on-going communication with regards to secondary research, and many non-athlete stakeholders advised regular communication and transparency will be crucial for the sustainability of this research. One participant summarized the difficulty researchers face when recruiting a younger population without providing them results.

> "I think it's a lot to ask [to participate in research without getting individual results]. I think most of the time when you're talking about professional athletes, they're usually younger and I think there's a lot of just maturation that happens even just through life. So, to ask a 18 or 21 year old, "Hey, for the good of society, for the good of science research, will you do this?" I think it's just a lot to ask, and…what I've seen is that people get frustrated when they don't have access to information or knowledge, especially when it involves their own, it's usually not their own specimens, their own tissue, but along those lines, it's usually something like, 'Hey, this is my information. Why am I not even understanding the results?'" 13:2 Non-Athlete Role

This participant also offered a means of improving transparency without necessarily providing individual-level results for secondary research.

> "So, I donated blood, […] and I just got a text from the Red Cross saying your blood is being sent to this hospital. And of course, it's not telling me which patient gets it. But it says, look, it's going to this hospital. It's going to help somebody in need…It's weird. It empowers you because you just feel like, okay, now it's no longer just this ambiguous what's actually happening, you know that your blood, your specimen is going to this hospital and it's going to help a certain person there, even if you don't know the specifics…Some information, I think, just lets you know, okay, this is what's being done. And even if I don't totally understand or appreciate it, nor want to, it's…that transparency." 13:2 Non-Athlete Role

Those athletes with research and/or medical experience advised that journal articles would not be the best form of communication for athletes more broadly, but these articles should be included.

> "I think it's important for athletes to understand how their body works and the way that it works, and I think that the research that I was in was a nice way to get involved with that. I think a lot of people, when they look at research, they're probably just like, "Oh, this is so much mumble jumble."
>
> […] I think if you can show them [athletes] and you don't, not names necessarily, but if you can say, "Oh these top professionals in these sports, this is research on their performance." That that would be more intriguing to them, rather than just like, "Hey guys, let's look at some research." And all the students are like, "Oh" [unenthusiastic exclamation]." 38:2 Athlete and Non-Athlete Role

One athlete provided an example of how information from journal papers had been provided to them in a helpful way.

> "I know he [their personal trainer] did a lot of research on his own and reading different journal articles and things like that, but I wouldn't be able to tell you what he was reading. It was more of, he was giving me at least [practical] information of saying, "We want to reach this mark because we want to make sure your body is recovering, it's resting, it's working efficiently." And so, I would get more of that general information." 40:16 Athlete

As discussed in the Athlete Characteristics Section, there was a universal consensus that athletes are curious about how their bodies work, and this research provides a mechanism for

them to be active participants in the discovery process. Building on how research findings are communicated, one participant cautioned strongly that the research products should not be promoted to the public as a means to becoming an elite performer or professional athlete (quote 11:24, Health Disparities Section). They also described how quickly relationships with third parties and athletes can breakdown quickly if athletes believe they are being represented negatively or their celebrity status is being manipulated (Record 11). Thus, all forms of communication with regards to athletes are either relationship building or destroying.

> "I do think we've had a couple of suboptimal corporate relationships where we've been partnered with the product, and then their social media team has gone crazy off of a negative event on our end. I think some of it is also whoever runs those interactions, the relationships with the outside providers, it's a real relationship as opposed to some sort of commercial entity." 11:2 Non-Athlete Role

Furthermore, participants spoke about athletes engaging with each other to get input and recommendations, everything from input on research (see Consent Section, quote 16:40) to whether to get a second medical opinion (see Athlete Considerations Section, quote 22:49). This feedback along with the other desires from athletes reported herein reinforces the need for the Alliance to be in regular contact with athletes: by engaging with them in decision making, providing participants with feedback on how samples and data are being used, and including them in reviewing public communications.

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3.3 Tables and Figures

Table 3.1: Recruitment Demographics

Characteristics	**Total**	**% Total**
Total	42	100%
Stakeholder Representation		
Professional Athlete	20	48%
Other Roles (Select All That Apply)		
Coach	5	12%
Physician	2	5%
Training Staff	2	5%
Team Management/Owner	1	2%
Agents	1	2%
Lawyer	1	2%
Sports Performance Researcher	1	2%
Other	8	19%
Employment Status: Active	5	12%
Gender: Female	8	19%
Non-Professional Athletes	22	52%
Non-Athlete Role Roles (Select All That Apply)		
Team Medical Staff	5	12%
Lawyer	4	10%
Training Staff	4	10%
Mental Health Professional	3	7%
Agents	2	5%
Union Representatives	2	5%
Research Team	2	5%
Team Management/Owner	2	5%
Sports Performance Researcher	2	5%
Coach	1	2%
League Representative	1	2%
Other	5	12%
Gender: Female	10	24%

Table 3.1: Recruitment Demographics Continued

Characteristics	Total	% Total
Sport Demographics		
Type of Sport		
Team Only	23	55%
Individual Only	10	24%
Both	9	21%
Sport Affiliation (Select All That Apply)		
Football	12	29%
Baseball/Softball	11	26%
Tennis	7	17%
Soccer	5	12%
Basketball	3	7%
Hockey	2	5%
Golf	1	2%
Other	14	33%
Gender of Sport's Affiliation		
Men's Sport	18	43%
Women's	12	29%
Both	12	29%
Participant Demographics		
Average Age	45	(26-69)
Race/Ethnicity		
White or Caucasian	37	88%
Asian	3	7%
Black or African American	2	5%
American Indian or Alaska Native	1	2%
Educational Attainment		
Graduated from high school or GED completed	1	2%
Completed some college	2	5%
Graduated from 4-year college	12	29%
Completed some post-college education	3	7%
Completed master's degree	7	17%
Completed professional degree or Ph.D.	17	40%
Willing to Collaborate with Researchers (Yes)	32	76%

Table 3.2: Inductive Codebook with Exemplar Quotes

Athlete Characteristics	Definition	Exemplary Quotes
Psyche	Discussion or stories related to actual or potential impact of performance ability and/or measurement on one's mental health, body image, identity, or self-esteem. Any discussions of interconnectedness or disconnect of sense of self or identity with one's body or physical ability. Also includes concept of grit or mental fortitude required to perform at elite level. Includes mental/personal impact of being measured.	"…you're used to your body not necessarily being yours, but in the control of somebody else's per se. A lot of times it feels that way, you do as you're told, and you're just controlling your body." 22:24 "I think that it [a research result of high injury risk] could be a plus or a minus. I think mentally, it would be negative. But I think for a training perspective, it would be a positive. But I think once you get into the mind negatively of an athlete, they can't compete. If you're not in that right mindset, you're not going to win. And I think that that's true of team and individual players." 38:23 "We've been through the physical aspect. I could take every single ground ball. I could take every single swing, but if I cannot perform in front of 10,000 people, then I don't have a job." 39:30
Life Course	Discussions about how athletes' experiences over time (through their career development/skill level) do or do not change one's reactions, opinions, perceptions to various factors, including research and other stakeholder groups. Includes changes in relationships and/or power dynamics through various stages of career, such as the team's influence on players in minor league vs major league. Includes expressed opinions about youth/child, college, pro, retired, minor vs major league differences as well as changes based on new/different roles- as a doctor or parent.	"Now, a lot of them, when they get to the tail end of their career or a lot of these athletes participate afterwards, they're concerned about their health. When they're young and they're going into it, they tend to feel more invincible. […] I think when they're getting toward the twilight of their career, they're much more interested and engaged…" 18:35 "I could see some parents getting hold of some of this stuff [HPR] and going crazy. Just, that's one thing I worry about at the youth level, is how it would trickle down and what that means for youth sports and parents trying to get their kids into whatever and maximize everything." 30:62

Table 3.2: Inductive Codebook with Exemplar Quotes Continued

Athlete Characteristics	Definition	Exemplary Quotes
Us/Them	Discussions of athletes' relationships with various stakeholders as being with them, against them, or moving between states. May include sentiments such as "are you with us or against us" or how the dynamic of friend or foe changes based on circumstances/situations, ex. "for the game, we're all on the same team afterwards it's front of the house vs players." Includes examples of stakeholder groups exploiting other groups (e.g., team staff or league trying to save money at the expensive of athletes or incentivize at expense of health), examples of stakeholders fighting for athletes against other stakeholders (e.g., unions or agents for athletes), or examples of positive relationships across stakeholder groups (e.g., athletes trusting team's training staff). Is not intended for discussions of within nonathlete stakeholder group variation or general descriptions of stakeholder group dynamics.	"…they're [agents and personal trainers are] there and they're paid by you, they're motivated to have you as a client, so they would definitely be another one who's on the players' side of the wall." 35:39 "The players all stick together and the staff all stick together, but when it's time to be a team, everyone's a team. But when it go time to negotiate, it's not like the coaches are looking out for the best interests of the players." 22:29
In/Voluntary	Discussions of ability or inability to make choices about oneself, including but not limited to, medical decisions, research participation, data collection and sharing, training, and personal life. Comments about voluntary or involuntary nature of experiences from athletes or other stakeholders about getting things from athletes (e.g., data). Includes importance of or lack of importance r/t needing to consent, give permission, or have a choice for data collection/measurement of self, including but not limited to research activities, including sharing data and samples, work-related performance reviews/analysis, college data collection.	"…if somebody gives consent and they understand that their samples can be used for future tests, as long as it's anonymous and they've given their consent, okay, then they understand that and that's fine. As long as they fully understand that. I do think there could be cases where people don't fully understand like what they're consenting for and possibly something is involved in some sort of research that they don't approve of." 30:59 "I wore a helmet in college and junior hockey. And I got to [professional training] camp […] and they told me to take my helmet off because professional hockey players […] did not wear helmets. […] Well, if everybody's not going to wear helmets, I'm not going to wear a helmet. Three or four days into training camp, I got high stick, just accidentally, got cut for 10, 12 stitches on my head, and I went, "The hell with this." And I put a helmet back on and I wore a helmet the rest of my career." 19:26

Table 3.2: Inductive Codebook with Exemplar Quotes Continued

Participation and Results	Definition	Exemplary Quote
Motivations	Examples and discussions of reasons to support or not support research. Statements such as "I would do this research because…" or "<my group or team> would not be interested in this research because…" Includes both athlete's and non-athlete stakeholders' motivations. May cover desire for healthy players, altruism, betterment of future athletes, contributing to personal cause, curiosity/personal edification, expectations from institute/team, money, personal improvement. May overlap with commodification, utility, and/or ROR.	"I think athletes are always curious. They're curious about performance. They're curious about other athletes […] They may not have anything that will come back, but they'll be curious about the whole process and find it interesting. So, I think you'll probably have fairly good participation." 15:21 "They [professional athletes] will be interested in doing this, in my view, if they think it has some immediate benefit to them. I don't mean financial benefit. I mean that results will somehow improve the safety life of the players. Some might be moved by broader objectives to just help the world, that volunteer." 12:2
Utility	Discussions of how the science/technology/research is or could be used by or for individuals or stakeholder groups. Clinical/medical applications, training changes, personal research applications, etc.	"They [researchers] say, "Okay. You're weak here, this could happen, so let's strengthen these two things and you have this rehab or prehab every day." I think that's helpful." 45:15 "So you need mass numbers [in a biobank] for not only treatment [but] performance data. There's multiple examples of drug companies finding a particular individual with some unique genetic finding that leads to lower cholesterol, and they make a drug around it, right? So, there's that holy grail of, "Hey, is there a particular genetic signature that is going to lead to increased performance?"" 10:12 "…on the performance side, I think it's [receiving results that are bad news are] nice. Because you could maybe tailor your strength and conditioning, or your workouts, and stuff like that." 38:24

Table 3.2: Inductive Codebook with Exemplar Quotes Continued

Participation and Results	Definition	Exemplary Quote
Quality of Information	Discussions of the quality of data and information derived from performance data and/or samples, including research and commercial endeavors. Also captures sentiments that the data/research would be scientifically interesting or would contribute to general knowledge. Examples may include quality of data, samples, or results from research, as well as quality of information from commercial products. Data quality ranging from junk to uncertain to high quality. Includes discussions of uncertainty in the meaning of the future research findings and/or individual results. May overlap with utility when questions of if the information learned will be of high enough quality that it can directly be useful for athletes.	"…a lot of information I think can be generated from that [survey research] especially when it comes to behaviors. Like how much do you train or sleep or what do you like to do to prepare for a competition? Or what do you do afterwards? Like there's great information for that. Unfortunately, it becomes very subjective." 8:6 "One elite athlete compared to another elite athlete is very different and there's so many ways to measure things now, but as I said, measuring's good, but if it's not actionable, if it's not something you're going to use, throw it out the window, it doesn't matter." 15:32 "…it's [HPR is] going to be able to help us delineate between the cruddy data and the actual, true, impactful data. And that's from a performance standpoint." 10:36
ROR	All discussions about the need or interest in receiving results from research study.	"…what I've seen is that people get frustrated when they don't have access to information or knowledge, especially when it involves their own, it's usually not their own specimens, their own tissue, but along those lines, it's usually something like, Hey, this is my information. Why am I not even understanding the results?" 13:2 "So, if there's not really result given back to the patient, if there's not good communication, I think resentment can build, and frankly, you'll never get sort of longevity in what you're trying to do." 16:4 "my initial thought is I would not be interested in this unless I could see the results." 22:70

Table 3.2: Inductive Codebook with Exemplar Quotes Continued

Participation and Results	**Definition**	**Exemplary Quote**
What's in it for me?	A subset of athlete's motivations that includes discussions of how they wrestle with the decision to participate in this research. May also include discussions weighing risks and benefits or the process of thinking about the various ramifications of participating in research.	"in thinking of participating in these programs, if you could illustrate an immediate payoff for me [...] I think I would've been more open to that because I'm getting something for it. […] this is very selfish, but this is the mind of an athlete, "What's in it for me?"" 34:58 "But at the beginning, people who are actively still on tour or playing professional sports, I can't see them just doing it for nothing…" 43:32 "As like a current professional athlete, I would say I'm not going to go out of my way and spend time and effort for something that isn't going to directly, I guess benefit me, just because of the schedule and everything like that and how busy you are." 22:39
Athletic Considerations	Discussion of potential impacts of research on athletic ability, such as pain or injury from invasive sample collection, time away from training, interfering with sport's season, etc..	"You'd be unlikely to get a professional athlete to agree to a muscle biopsy because again, that's a more invasive test. Getting blood, things that is, would be less of an issue." 6:2 "If it's something that gets in the way of trying to build a winning team, that creates dissension in the locker room, if the testing were done at the wrong time." 7:18

Table 3.2: Inductive Codebook with Exemplar Quotes Continued

Participation and Results	Definition	Exemplary Quote
Non-athletic Considerations	Inverse of athletic considerations that do not fit into athletic considerations. May include concern or impact on things not related to performance, such as career, money, public image, etc.. Also includes discussions of how research, data, results, or measurements may be used against an athlete. May include trust or mistrust of use by other non-athlete stakeholders (including researchers, teams, etc.).	"The biggest reason in my book not to participate is if there's a financial stake coming up on the line. I mean, you get so few bites at the apple, and teams are so good at using the data to try to devalue players. That's, to me, the main reason." 25:15 "A kid achieving a dream, whatever it may be. It's not about the money, that separates it from us. Kids that go from high school to college, they just want to play at that level, be able get have a chance to get a free education. That's they're doing it for. And the same thing to me from college to pros is, does it affect your ability to do what you say you want to do? Will it stop you from achieving your dream?" 32:46
Dis/Trust in Science	Specific subset of non-athletic considerations. Discussions of individual's or groups attitudes towards science, research, and/or researchers. May include sentiments surrounding COVID policies, unfamiliarity with research and/or science, etc..	"It's not unlike, honestly, a lot of the discussions we've had with just COVID protocols, vaccinations, things like that. There's a lot of just general, I'd say, there's just not a lot of trust in science in locker rooms. It's certainly, I don't think, ignorance or anything like that. It's just that that's not the environment that people grew up in." 7:15 "I don't have a problem with it [the biobank] because I have the trust in scientists and doctors and I wouldn't think that they would want to do something to harm us. I think that they would want to help the next generation." 28:19
Controversial	Discussions of any application of research as potentially controversial, questionable, or nefarious. Might include examples of doping, eugenics, cloning, stem cell research, enhancement, or changes in existing standards. Include discussions of research driving health disparities, promoting ideas of master races, or limiting access to sports to individuals or groups.	"I can also see a lot of fears about the use of your body matter for things that you don't know. So worst case scenarios are like cloning, weird recreation of Frankenstein like animal things that none of us even know exist yet…" 31:23 "You have other societies with different world views than ours that see no problem in trying to mix a human and a rat [in] a test tube." 22:56

Table 3.2: Inductive Codebook with Exemplar Quotes Continued

Data Collection, Management, and Use	Definition	Exemplary Quote
Measurement	Examples and discussions of when athletes are measured and/or have samples or data collected about them. Emphasis on the act of being measured, from either perspective of the one measuring or one being measured. Can include trainers, team physician, work-related physicals, private physician or trainer, research activities, QI data collection, institutions that athletes are affiliated with (teams, colleges, leagues, player's associations, commercial companies, etc.)	"I mean, a lot of athletes right now they're analyze[d] and overanalyze[d] right now. And when you sit there, and now you go to the combine with an old meat market. Where they're looking at you and they're going through analyzing everything going on. And people are picking and pulling at you at the combine, to see what's wrong and overanalyze with MRI scans and everything else." 32:43 "I feel like sometimes testing also, you feel like as an athlete, you're being quantified by these objective measures, which can't really, fully also show your potential and your ability. And there's so many things about being an athlete. And not so much the sports performance testing, but we would do all this, for our testing, we'd do a speed, a sprint test, a four yard dash and a different... All these different tests that break down all these elements of your athleticism. And sometimes as the athlete, I felt like I would score worse on some of those things, but as a soccer player, I was very good. And so sometimes that stuff can be a little mentally challenging, I guess." 30:47

Table 3.2: Inductive Codebook with Exemplar Quotes Continued

Data Collection, Management, and Use	Definition	Exemplary Quote
Commodification	Discussions of value, ownership, and exchanging of samples/data and/or subsequent products/derivatives for benefit/incentive, including more ambiguous discussions of direct personal benefits from the research. Includes references to products or revenue. May overlap with motivations, utility, and/or ROR.	"Property and ownership. What if I give my sample, even though it's de-identifying and anonymous, but it's some cool new product or life saving whatever, comes from it and why would I not get credit or whatever […] And I think if the way it helps people didn't necessarily mean that the proprietor or whoever the person is creating, like all of a sudden makes gazillions of dollars, then there's less of this like inequity like, "Hey, that came from me." And they're now like bazillionaires and I see none of it." 8:42 "Poor high school kid or poor college student, 'how much do I have to pay to get this information?' And if there's no cost to you, then yeah, probably [participate in HPR]." 35:31
Confidentiality	Discussion of ways in which one's identity is not shared. Includes ideas of anonymity, de-identifiable data, data aggregation, data protection, security, absence of leaks, notions of secrecy. Includes examples where personal, private, or information otherwise believed to be confidential data is shared (such as sharing of medical information without explicit permission).	"I mean, confidentiality looks like it doesn't have a face or a name. […] Even though you're not saying names, there are so many different ways to figure out even if you don't give it away. I just don't see. I mean, I know you have to have a coding sequence, so to speak, to make sure elite athlete, wide receiver, 1, 2, 3. Middle tier, wide receiver. I mean, you have to have something that goes into it, but it has to identify exactly what you're trying to do. And so for me, some people may not be as concerned about confidentiality…I don't trust anything to be confidential anymore." 32:64 "And so, that would just be my kind of awareness would just be thinking about, okay, is the benefit here worth whatever else is happening. But, just related to muscle biopsy, I think it's just in general, you keeping my tissue for whatever reason and how you de-identify, that's probably one of the biggest issues because [...] That's probably one of the things that it surprises me the most, is how few teams de-identify their data into the Cloud." 11:18

Table 3.2: Inductive Codebook with Exemplar Quotes Continued

Data Collection, Management, and Use	Definition	Exemplary Quote
Access Control	Discussions of who should (or should not) have access to samples and data, includes temporal or circumstantial nature of access rights if variability depends on contexts. Discussions about who and how data/sample sharing decisions are made. Includes recommendations for who should be making such decisions.	"…making sure and addressing confidentiality, data protection, privacy what sort of certificates of confidentiality are going to be in place if a team, as a part of a grievance process sub tries to subpoena records? What protections are in place? And then from the taking a step earlier in the timeline, predictive analytics are going to be a concern for guys because, just because I have a steeper tibial slope doesn't mean I'm going to get an ACL tear. And clubs, whether it's true or not, I think it is, but whether it's true or not, players will often think a club is going to use information against them." 21:7 "This interest in knowing and controlling how samples and data were used was especially important with regards to studies seeking to use DNA." 12:18
Privacy	Discussions of being a 'private person' or 'not wanting all of one's information out there.' Includes all general or vague references to privacy or gesturing to privacy that do not meet threshold for Confidentiality, and Access Control.	"I really don't know if a player has a personal life, to be honest with you anymore. I think everything is team business." 32:53 "…our life is on the phone and stuff and they probably have all my info anyway[…] They already know everything about me." 23:38

Table 3.2: Inductive Codebook with Exemplar Quotes Continued

Miscellaneous	Definition	Exemplary Quote
Suggestions	Feedback on how research team could/should conduct research: from how to recruit athletes, to marketing research, results, products, business designs, and what to study. Does include recommendations of who should or should not be 'at the table' to decide how research is designed/conducted.	"So, I donated blood…And I just got a text from the Red Cross and your blood is being sent to this hospital. And of course, it's not telling me which patient gets it…But it says, look, it's going to this hospital. It's going to help somebody in need...It's weird. It empowers you because you just feel like, okay, now it's no longer just this ambiguous what's actually happening, you know that your blood, your specimen is going to this hospital and it's going to help a certain person there, even if you don't know the specifics…I feel like it crosses over to what you're asking, it should. Some information, I think, just lets you know, okay, this is what's being done. And even if I don't totally understand or appreciate it, nor want to, it's…that transparency." 13:19 "I think if that study [HPR] was to succeed, it would have to start with guys who were already established and/or made enough money to where they're feeling comfortable in their career and their choice." 39:8
Sci/Tech	Discussions about the individual's experience with science or technology in sport, including lack thereof (such as not being allowed water while training)	"We had a day last week that it was 105 or so, and I just went over to the head coach and I said, "Look, you got to allow the kids to take off their helmets to give them a chance to cool off. And '60s and '70s had a lot of that, "Don't drink water. Here's a salt tablet." For me, I was with the [TEAM], I had a teammate, his name was [ATHLETE'S NAME] who passed away because of heat exhaustion. […] I took advantage of cold tubs and contrast between hot and cold to try to keep everything functioning properly, but you just need to continue to find ways to do that." 35:14 "One example that was very predominant in baseball and it's now spread across pretty much every sport is data analysis and analytics. […] There have been measurable changes and measurable results in how the game is played, what the players do, how they train, all those things." 6:5

Table 3.3: Structured Codebook with Exemplar Quotes

PRISM Contextual Factors	Definition	Exemplary Quote
Characteristics of the Organization	Characteristics of researchers, teams (including staff, MDs, coaches etc.), leagues, agents, Players Associations/Unions Includes historical examples, interactions, motivations, etc.	"Stay far away from management and leagues […] I just think if it's league involvement, unless the league and the PA [players' association] joint participate in this, then it seems like there's a nefarious reason for collecting all this data. The crux of it, that's the issue you have is this data can be used against me. I think it's just human nature to not want your employer to have this type of data… PAs look after the player." 26:72 "We [a professional team] definitely want to do it to aid in the development or health maintenance of that player. It's not always viewed that way." 7:10
Characteristics of the Recipient	Characteristics of the athletes. Includes beliefs, experiences, interactions, etc.	"I think athletes are generally curious about their body, that everyday they're evaluating their capabilities for that day and they want to understand why they're getting better, or how they perform, or even gaining any sort of edge." 26:4 "…you feel like as an athlete, you're being quantified by these objective measures, which can't really, fully also show your potential and your ability. And there's so many things about being an athlete." 30:47
Intervention: Biobank	When the discussion is focused on the biobank. Can be used in combination w/ HPR when it either overlaps or is unclear which intervention is being discussed.	"And I don't think it's obligatory to say, "Hey, we're going to look at your human performance, get this data." […] I don't think it has to be, if you do this, then you have to be part of this biobank." 13:20 "It's the open ended forward looking nature of it that I have the most problem with." 29:27
Intervention: HPR	When the discussion is focused on the human performance research. Can be used in combination w/ biobank when it either overlaps or is unclear which intervention is being discussed.	"I think the athlete really needs to be a part of the collaborative piece of it and not just be on the end user side of it…Because it [HPR] really is an invasive experience. And so being able to not only contribute to the research, but be a consumer of it and utilize it, I think is extremely important for the athlete experience." 17:3 "I keep trying to bring it back to humans and what do we see in terms of disease? What do we see in terms of health outcomes? What do we see in terms of longevity in sport? More so than the cellular level because if we're not applying this to our actual players and our patients, then it's all just play to me. It's all just fun science." 20:50

Table 3.3: Structured Codebook with Exemplar Quotes Continued

PRISM Contextual Factors	Definition	Exemplary Quote
Implementation Strategy and Sustainability Infrastructure	Discussions of barriers and facilitators to research implementation in the organizational processes and infrastructure. May include recommendations for strategies on how to make changes to accommodate research. May overlap with Implementation Outcome and Organizational Characteristics.	"So I guess, I mean, if from an enrollment standpoint, it would be nice, what's in it for them, but boy, that is a huge logistical challenge […] part of it depends on how much money you've got in your funding mechanism, right? So if you've got 10 FTEs to deal with, 10,000 phone calls about what does this mean, then maybe it's worthwhile. But if you're running a barebone ship, I'm not sure that the risk of all that data and releasing it individually to patients is worth it." 10:31 "I just got a text from the Red Cross and your blood is being sent to this hospital. And of course, it's not telling me which patient gets it…But it says, look, it's going to this hospital. It's going to help somebody in need...It's weird. It empowers you because you just feel like, okay, now it's no longer just this ambiguous what's actually happening, you know that your blood, your specimen is going to this hospital and it's going to help a certain person there, even if you don't know the specifics. […] I feel like it crosses over to what you're asking, it should. Some information, I think, just lets you know, okay, this is what's being done. And even if I don't totally understand or appreciate it, nor want to, it's […] transparency." 13:19
External Environment	Any structure or organization outside of the target sample. Includes society at large, media, countries, etc. Also includes indirect external factors, such as experiences with wearable technologies, that may impact how research is received in general. Includes discussion of previous or non-Alliance research as well as historical examples of how research and/or measurement or technological advancements were implemented/conducted within this population by non-Alliance activities, such as measuring athletes within a team setting. Includes legal issues such as ownership and/or property rights discussions.	"Other unions, you have the teams doing this wearable technology to study, to collect a lot of data on players and try to decide like what's better for training, how often they should practice, things like that. The big issue the players have there, the unions, is consent and confidentiality, and not having the data commercialized. This whole concern that people are going to sell this data for gambling, and so there are issues that surround that." 12:18 "So in the pros, there's a genetic non-discrimination act […] The NCAA has not, to my knowledge, gone that far." 10:7

Table 3.3: Structured Codebook with Exemplar Quotes Continued

RE-AIM Outcomes	Definitions	Exemplary Quote
Reach	Things that impact the research's ability to reach targeted population, professional athletes. Includes reasons why people would not participate, details about who would be excluded or why/how, demographic characteristics and sample size of recruited sample, attrition, representativeness, and dissemination of findings to target population who may benefit from it.	"I guess what's really hard on the biobanking is getting people to sign up, right? And so there's got to be a reason for them to do it, and that reason could be, "Hey, they're just good people and want to contribute to science," or they want some personal feedback or personal reward, whether that be financial or scientific or knowledge-based, or there has to be a coach, player, agent, parent, et cetera, telling them to do it. So you're going to have to target... If you're looking to maximize your numbers in the biobank, you're going to have to target people other than the athletes, depending on the level of play that you're looking at." 10:16 "Especially as it relates to representative sampling, making sure your research population represents the cohort you're opining on and everything down to the wearables you use. Would a data collection methodology have some sort of disproportionate impact if you had darker skin tones? Right. We've seen that. It's issues like that. And thinking about that all the way since the beginning and articulating to the participants, how you're going to address that." 21:39
Effectiveness	Ability for the research to collect, store, and share samples, to achieve research goals (moonshots), results of the research- behavior changes, impact, and unintended consequences.	"…the majority of those [research priorities], until you get to your phase of moonshot [/priority] four really, again, gets into very, very, very thin slices what might be happening at the cellular level or the muscular skeletal level. I think the one missing thing right now, but you do grab it in moonshot four, is both the psychological drivers, if we will, both in just pure cognitive function, kind of the motivational drivers of why people do what they do, which is very definable…" 42:6 "If you're looking to maximize your numbers in the biobank, you're going to have to target people other than the athletes, depending on the level of play that you're looking at" 10:16 "If you discover you have a predisposition to not metabolize a brain injury, you might decide not to go into football, for example. And those kinds of tests, ultimately, I can see being developed down the road." 16:28

Table 3.3: Structured Codebook with Exemplar Quotes Continued

RE-AIM Outcomes	Definitions	Exemplary Quote
Adoption	Things that would drive non-athlete stakeholder adoption of the research- both positive and negative. Includes dissemination targeted to various organization-level stakeholders, such as clinicians, trainers, etc.	"I'd want to learn as much as I could about this performance data and utilize it to get your player to the right physical therapist, for example. He's got a little bit of an issue here we're picking up with his quads relative to where you probably ought to be. Who out there is the best at therapy for the quads? So that's the kind of thing I would think would be beneficial as an agent." 25:16 "So, I'm always very hesitant of if it feels too much like a science project, you're not going to get the best coaches involved in it. You may keep their interest in so to speak and what's some of the data, but it really has to be actionable." 15:11
Outcome: Implementation	Includes recommendations of adaptations to research design or methods, like data protection. Also includes ways that the researchers should implement the research- including marketing or having a trusted member of the community as a spokesperson.	Not Applicable in Exploratory Phase. Pending actual implementation process assessment.
Outcome: Maintenance	Things that impact the continuation of the research beyond implementation. Stakeholders remaining engaged or discontinuing their relationships with the alliance for example. Ways that the research can perpetuate more research and have larger impact beyond moonshots.	"I think there's numerous problems with trust among the athletes and where that information is going to go and what it's going to be used for. [...] And now in the age of the internet and data leaks, et cetera, I see it as a real problem for [data and sample] collection and professional athletes. And I would think there'd be a lot of resistance on the athletes themselves as well as among the agents and other involved parties on the athletes' side to unrestricted use of their genetic information." 10:11 "I think it depends on, like most things, what we as clinicians understand about it [HPR results in the clinical space]. So, knowledge is power only when you understand what it means. So, if we just get a bunch of numbers or values that we are just not educated about, I don't know how useful that is. […] a lot of the information while it's really interesting unless we get dedicated education, unless we're working with a team that can really help us interpret it, a lot of it's noise, and a lot of it is confusing." 13:7

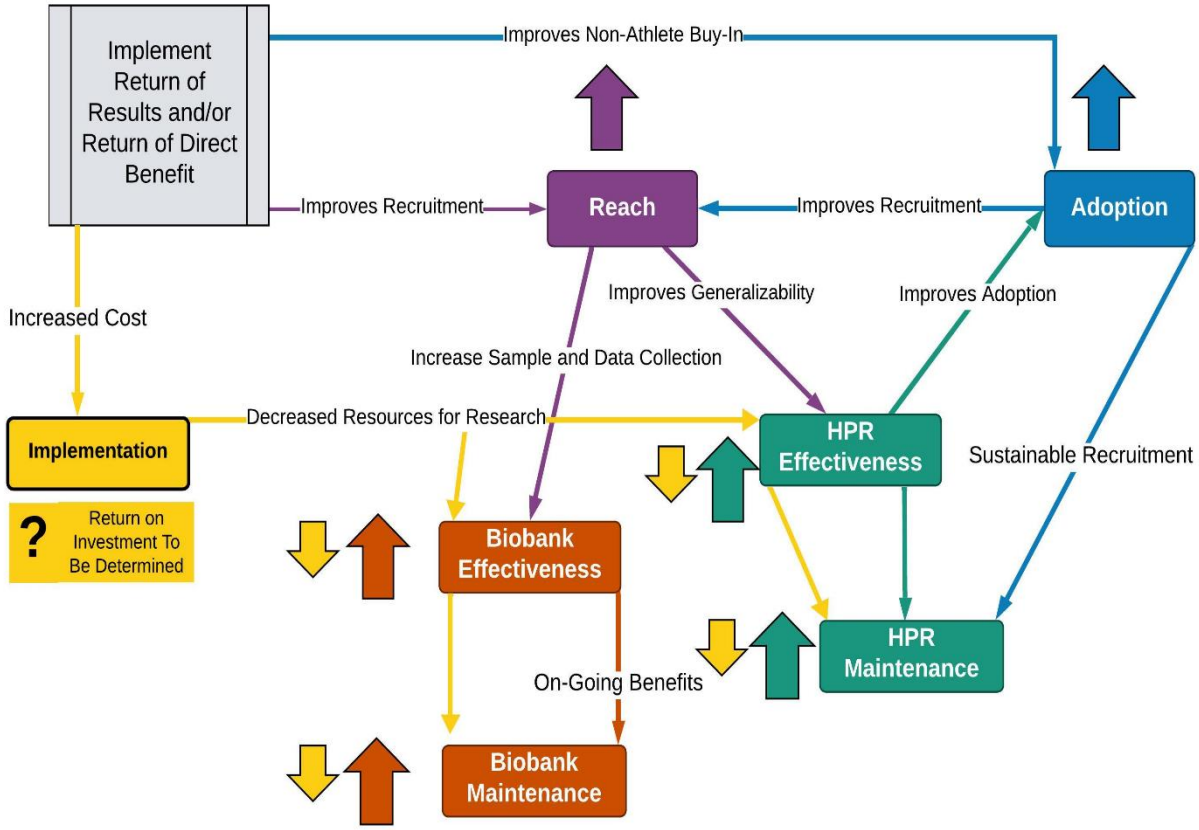

Figure 3.1: Implementation Outcomes for Returning Results in Human Performance Research:

This figure shows the anticipated changes in implementation outcomes as a result of researchers including direct benefits for participants in their studies. Receiving a direct benefit is anticipated to increase enrollment, which is expected to improve the generalizability of the samples and data. Thus, an increase in human performance research's (HPR) and the biobank's Reach and Effectiveness outcomes. Research that provides a direct benefit to athletes is expected to improve non-athlete stakeholders buy-in, and this will improve the Adoption outcome. Similarly, improved effectiveness of HPR is also expected to improve Adoption by non-athlete stakeholders who would then be more likely to recommend athletes participate in this research. However, the costs associated with returning individual results will result in less funding for research initiatives. Therefore, researchers will need to determine how much investment is appropriate to balance the improved recruitment against the costs associated with returning individual results.

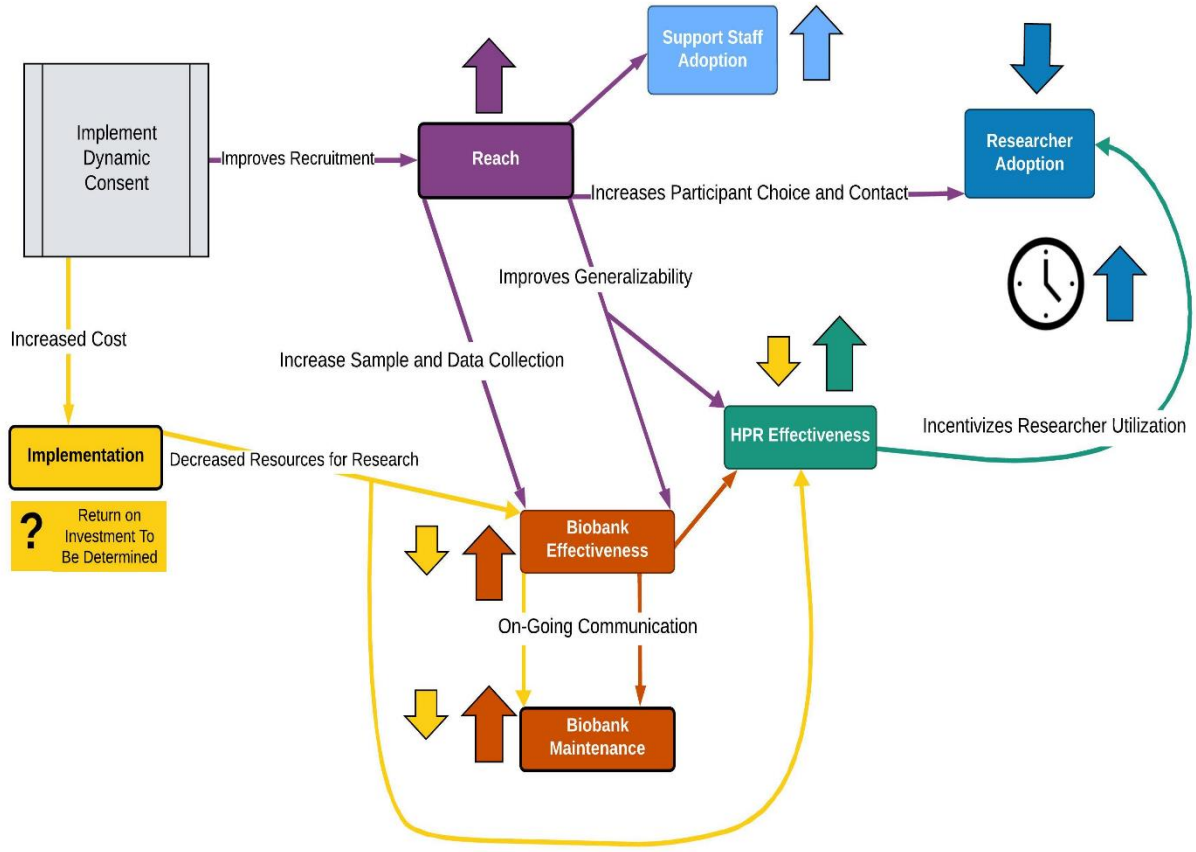

Figure 3.2: Implementation Outcomes for Dynamic Consent in Biobank:

Diagram of the impact of study-specific, dynamic consent as an implementation strategy on implementation outcomes. Improvements in autonomy are expected to improve Reach and Adoption by non-athlete support staff. It is hypothesized that increased autonomy and transparency will improve enrollment and increase research acceptability for marginalized communities, resulting in improved generalizability. This increase in samples and data and improved generalizability will improve the biobank's Effectiveness and translate to improvements in human performance research (HPR) Effectiveness. It is anticipated that the introduction of participant consent and additional time and effort for researchers to communicate with participants will initially decrease researcher Adoption for some portion of external researchers. However, the improved generalizability and subsequent improved quality of HPR may incentivize external researchers to increase their Adoption of the biobank with dynamic consent over time. Finally, the research team will need to balance the increased costs associated with offering dynamic consent against the decrease in resources for direct research. It is expected that the dynamic consent costs would primarily occur in the development and deployment of the consent process. Furthermore, if the dynamic consent offers an opt-out option, participants can choose how much time they wish to invest in managing the use of their samples and data without necessarily hindering the exploratory research if they wish not to engage with this feature.

CHAPTER 4: Discussion

4.1 Discussion of Study Findings

This study demonstrated how DIS could be adapted and applied to Precision Health Research. By applying DIS, this study utilized the Implementation Strategy of community engagement to inform the design and delivery of two Precision Health Research interventions: HPR and Biobanking with aspiring and professional athletes in the US. By examining the contextual factors of the sports industry and stakeholders related to implementing these research interventions, this study was able to identify logistical, ethical, legal, and social implications associated with these research interventions. More importantly, this study collected data from the key informant interviews that was able to identify many implementation strategies for how these interventions and the research practices and policies could be adapted to make the research interventions more acceptable and accessible to aspiring and professional athletes and their related stakeholders. Barriers and facilitators to Precision Health Research with professional athletes in the US have been summarized in Figure 4.1 along with the stakeholder recommendations for future engagement activities.

These implementation strategies reported in the Implementation Results Section were based on the contextual factors reported in the interviews and targeted the most over-arching barriers reported by athletes. The major barriers identified in this section align with many barriers from Precision Medicine research. Specifically, genomics research brought the desire to have research results returned to participants, raised questions about confidentiality concerns such as the potential for genetic discrimination, and the acceptability of future research with genetic data.[21,22,103,114,115,224,225,235-242] As a result, numerous recommendations of possible changes for how these barriers may be overcome in Precision Health research borrow best-

practices and emerging solutions from Precision Medicine's literature. Example of change made in Precision Medicine include genomic research was able to clinically confirm symptom-driven research results and facilitate the return of result process by utilizing the healthcare system.[243,244] Discrimination concerns led to federal and state laws prohibiting genetic discrimination, creation of certificates of confidentiality, and additional protections for vulnerable populations excluded from these laws (such as enhanced protections for military personnel).[240,245] However, athletes have an increased risk for discrimination related to legal loopholes or enforcement failures of the Genetic Information Non-Discrimination Act (GINA) and the American Disabilities Act.[114,246,247] Therefore, this study recommended adaptations to traditional research practices, establishing policies and practices to encourage representative sampling and minimize risks for discrimination.

To improve transparency and allow participants to control their data and samples in secondary research, researchers have explored restricting usages at the initial consent or allowing participants to consent iteratively with study-specific, dynamic consents, a legal requirement in the European Union.[229,248-250] However, other shared concerns such as the possibility of re-identification from "de-identified" data have yet to be solved but have been proven to be valid concerns.[251-256] The risk for re-identification for aspiring and professional athletes, however, is much higher than that of the general public due to the large amounts of publicly available health information. Similarly, athletes' celebrity status and the legalization of sports gambling also increase the desire to re-identify athletes' research information. Borrowing from this literature, Implementation Strategies were proposed and discussed in terms of the impacts on the various implementation outcomes and prioritized by their likelihood of improving the generalizability of the research interventions. Finally, professional and aspiring athletes have legal rights over their

name, image, and likeness, which may extend to any data that is identifiable. These legal rights may change how commercialization of research endeavors are structured, and these rights may be worth extending to all participants regardless of celebrity status. However, should aspiring and professional athletes be legally eligible to seek compensation or have more control over how their samples and data are used by researchers, the extension of these same privileges to all research participants may be required in the future.

The findings reported in the Implementation Findings include the thematic results, which are included in much greater detail in the Results for the White Paper Section. Many of these larger thematic findings are also similar to the existing literature. The misconception that participating in research gives one access to clinical-grade services, also known as therapeutic misconception, is pervasive in biomedical research as well as biobanking and will need to be considered in how any direct benefits, or lack thereof, are framed for participants.[226,227,257,258] Similarly, there is a new trend that pushes research to return more meaningful benefits to the community as well as the individual.[56] Alongside this trend are concepts of sample and data ownership.[49,259] However, expansion of Name, Image, Likeness (NIL) licensing rights may give athletes more claims to ownership and profit-sharing than the general public, or it may perpetuate a false sense of entitlement to benefits generated from research using their samples and data.[260,261] The need for on-going engagement and shared decision-making is also a common theme in biomedical research, which was particularly relevant for addressing the lack of diversity in Precision Medicine research.[45,51,59,60,66,67,70,106,137] Engagement and enhanced consents have also been discussed in terms of identifying morally questionable research as these activities allow participants to apply their own value judgements to determine what is and is not an appropriate use of their samples and data.[21,22]

In addition to the increased risks for discrimination athletes face due in-part to their medical records also being part of their employee files, their increased risks for re-identification, and increased sense of ownership over samples and data, this study found several concerns about Precision Health Research that were unique to athletes. One concern was that by participating in research an athlete would be giving away their 'trade secrets' and thus helping their competitors attain their skills. Similarly, the research itself may provide more benefits to the up-and-coming athletes than to the participants, and again this more rapid achievement in younger athletes may risk shortening participants' careers. It was also discussed how the ability to more objectively identify elite performers earlier may lead to negative impacts on sports participation, such as exclusionary practices or undervaluation of 'grit.' There were also concerns that HPR participation by children would unduly increase pressure for minors to obtain elite status and thus be harmful to these children. Finally there were concerns that the research would lead to new ways of doping and provide performance enhancing interventions that are too expensive for most athletes or members of the public to afford.

Drawing from the barriers identified in these interviews and strategies to improve the acceptability of research interventions and diverse research recruitment, broader and more detailed recommendations have been proposed for the Wu Tsai Human Performance Alliance leadership and researchers of ways that they can adapt their research policies, practices, and study designs to minimize the risks of participation for aspiring and professional athletes. However, these recommendations will need to be weighed against feasibility and logistical considerations as many require financial and staffing investments. The results of this study provide numerous possibilities for the Alliance to consider that may improve the acceptability and accessibility of this research for aspiring and professional athletes. However, regular

measurement of the potential and actual impact that these changes have on both recruitment and overall generalizability of the participants will need to be weighed against the potential and actual costs to the research goals. Nonetheless, these findings and implementation outcomes provide a roadmap for how researchers can think through their own values to make data-driven decisions about how resources should be allocated and what will ultimately be their measure of effectiveness. The recommendations are listed below that align with the thematic results and include additional background information on relevant concepts. The major themes have been visually linked to potential policy and design adaptations anticipated to improve acceptability and accessibility in Figure 4.2.

4.1.3 White Paper Recommendations

Note: To minimize duplication of text, this section includes the Introduction, Executive Summary, topical background information and recommendations from the White Paper.

Introduction

The Wu Tsai Human Performance Alliance's (referred to as the Alliance henceforth) mission "to optimize performance and catalyze innovations in human health for all" is at the cutting-edge of the transition from Precision Medicine, which studies disease states, to Precision Health, which focuses on states of extreme health but also includes Precision Medicine.[1,5] Precision health research, including HPR, by definition requires researchers to obtain high quality information about unique characteristics of research participants (phenotypes).[2,7] Traditionally, Precision Health studies have included an array of omics research, such as genomics and epigenomics, and have expanded to include digital technologies, most often wearable devices.[82,262] In more recent years, Precision Health research has turned towards N-of-One studies, or single participant studies.[263,264] Although Precision Health and Precision Medicine share many ethical, legal, and social implications of the research itself, transitions like this require evaluating the unique concepts of the new research and the potential impact on research participants. This evaluation requires exploring if and how the Alliance's research can achieve the two primary goals, optimizing performance and catalyzing innovations for all. The Alliance has identified five moonshots and the creation of an Innovation Hub to guide their mission to optimize performance.

Another key component of the Alliance's mission is to catalyze innovation, and to do this, the Alliance is creating a new biobank to collect, store, and share health information and biological samples for future research beyond the Alliance's own research. Biobanks have long

been the gold standard for facilitating large scale Precision Medicine research, and there is a wealth of literature available that addresses the many ethical, legal, and social implications of biobanks often addressing the specific context in which the biobank operates.[239] Acquiring in-depth phenotypic and omics details for samples with similar characteristics, such as elite performers, is often very expensive and resource intensive. Therefore, to facilitate Precision Health research, researchers include all research participants in a biobank, which collects, stores, and shares health information and biological samples, or a data repository, which excludes samples but may include omics data.[101] Academic institutions, medical centers, departments of public health, and government organizations all have and use both biobanks and data repositories for secondary research.[265]

With the growth of Sports Genomics, discussions of the ethical, legal, and social implications of genomics research with elite athletes have grown. Sports-related professional organizations and research consortia have issued several policy statements regarding controversial topics such as genomics biobanking and gene-doping.[2,7,99,113] One anthropological, legal, and ethical assessment highlights the need for researchers and stakeholders to address potential benefits, safety issues, and discrimination sports genomics may have in sports medicine programs.[114] The Athlome Project Consortium, a mostly European-based collection of Sports Genomics researchers, joined forces in 2015 to share samples and data in a collective biobank to facilitate genomic discovery.[7] The Athlome researchers sought to establish ethical principles and found that governance and participant protections varied between countries and institutions.[7,99] Issues of broad consent, rigorous anonymization in data collection, storage, and/or analysis, increased risk for confidentiality of public figures, commercialization, and appropriateness of clinical applications were identified.[7,99,113] The International Federation of Sports Medicine

(FIMS) has engaged with Athlome on these issues and since conducted their own assessment and recommendations for sports and exercise genomics research to reinforce athlete protections, particularly privacy and vulnerable populations, mitigation against inappropriate use of genomic information, including commercialization and gene-doping, intellectual property rights between countries, and issues related to returning genomic results to athletes and research validation.[2]

However, despite the various researcher-led recommendations for sports-related research, there is little existing literature about professional athletes' knowledge, attitudes, and beliefs about HPR and/or biobanking, or even research participation more broadly. The literature that does address the potential barriers and facilitators to conducting Precision Health research in this community generally lacks data from the athletes themselves, with only a few studies that surveyed professional athletes about genetic testing practices.[2,3,7,18,99,113,117,266] Findings from the survey studies related to screening and genetic testing found that athletes were concerned about potential discrimination in play-time, access to training, and their ability to participate in sports.[12,18,117,118]

At the initiation of this study, a wide number of potential cohorts of elite athletes were discussed, including professional athletes, Olympic athletes, college athletes, child athletes, and elite military personnel. Each cohort has unique factors that impact their research participation risk-benefit profile. Of the various potential cohorts, professional athletes were determined to have the most extreme risk-benefit profile.[114] Furthermore, Professional athletes also afforded the research team with individuals who often could also speak to their experiences as aspiring professional athletes, often including being child and college athletes. Designing research policies and procedures to be suitable for professional athletes, one of the most extreme use-

cases, is anticipated to confer benefits to any other categories of athletes, particularly those aspiring to perform professionally in the future.

Due to the novelty of the Alliance's research mission, this study sought to explore the perceptions of HPR biobanking amongst professional athletes and non-athlete stakeholders in the US to inform the implementation of the Alliance's HPR biobank at the University of California San Diego (UCSD). This study sought to separate the concepts of HPR and biobanking to minimize participants mistakenly conflating the two research activities. Despite this effort, many participants spoke about their interest in receiving results from future research conducted via the biobank despite the study explicitly stating that biobanks do not traditionally return results. The distinction between these two research initiatives was reinforced during interviews as appropriate, and the two research concepts only minimally overlapped. As such, the findings of this study are expected to be relevant to the Alliance more broadly than the biobank team at UCSD.

This White Paper provides a summary of the ethical and logistical issues related to HPR and biobanking in the background sections. The summary sections summarize the findings of this study, and the recommendations sections suggest how research practices and policies may be created or adapted to minimize risks to participants and improve research acceptability. The Conclusion Section seeks to unify the existing literature, study's results, and recommendations by providing examples of how multiple factors can be addressed with implementation of various suggestions and best-practices. A summary of the major findings and recommendations can be found in the Summary Table. Additional details about the study's recruitment and design can be found in the Appendix, and additional study materials are available upon request. Bookmarks have also been added to facilitate navigating between sections of the document.

Individual participants are referred to in gender-neutral terms (“they”) to facilitate anonymity. Athlete participants were evenly split between men and women. Amongst the non-athlete stakeholders, eight of the 22 participants (36%) were women.

Executive Summary

This study recruited 42 professional athletes and non-athlete stakeholders for one-hour, semi-structured interviews aimed at understanding the knowledge, attitudes, beliefs of HPR and biobanking and to identify barriers and facilitators to recruiting professional athletes. Thematic and structured codes were developed and a minimum of two researchers conducted consensus coding for both code types. Of the 20 professional athletes enrolled, 8 (40%) were women, and 10 of the 22 non-athlete stakeholders (45%) were women. However, all individual participants are referred to in the gender-neutral terms "they/their" to facilitate anonymity. Despite this study's efforts to actively enroll participants from a wide variety of backgrounds, lived experiences, and races/ethnicities, this study's participants were primarily non-Hispanic White (37 of 42; 88%). See Appendix: Study Description for additional information about the study's methods.

Main Study Findings

Overall, all stakeholders reported a high interest in HPR and most reported biobanking to be acceptable. Most athletes would consider participating in both forms of research. Perceived benefits of research participation included satisfy curiosity, ability to learn more about their performance, potential to improve their performance, gaining access to otherwise unavailable or unaffordable technologies and experts, and general concepts of altruism.

However, several real and potential barriers were identified: vulnerabilities of aspiring and professional athletes, questions of the impact of the research, the need for direct benefit to participants, and the importance of empowering athletes in the decision-making process.

Vulnerabilities

Vulnerabilities include characteristics of the athletes themselves that impact their willingness to participate in research (Athlete Characteristics). These characteristics include resources, experiences being measured and evaluated, and variability in participation over an athlete's life course. Generally, participants viewed potential risks for research participation of professional athletes extended to those aspiring athletes, so researchers recruiting athletes who may become professional athletes in the future should consider modifying their research policies and practices to account for future risks, particularly with regards to confidentiality and potential discrimination.

Another major vulnerability identified was related to the large amounts of athlete's health information already publicly available, experiences with discriminatory practices using health information, and the increased value of athletes' health information (Section 4: Confidentiality and Discrimination).

Research Effectiveness

Questions about the effectiveness of the research included its ability to be generalized to the public (Section 5: Research Effectiveness) and potential for exacerbating existing disparities, both locally and globally (Section 6: Disparities). The need for the research to be representative and diverse was raised by multiple participants along with the potential for this research to further exacerbate health disparities. Other questions related to disparities centered on whether the Alliance could equitably share data and samples with researchers worldwide, pointing to low resourced researchers lacking infrastructure to utilize these resources. Questions of eugenics and whether the purpose of studying elite athletes was to create a master race were raised by several participants.

Return of Direct Benefits

Most participants, both athletes and non-athlete stakeholder roles, believed that for athletes to participate in this research, they would need to benefit directly from participation. Participation was described as a cost-benefit ratio where the costs were an athletes' time, energy, and relinquishment of private information and biological samples. Returning study results to athletes was a major perceived benefit expected from research participation (Section 7: Return of Results). However, athletes are also accustomed to the commercialization of their health information, name, image, and likeness (NIL), and being empowered to own and/or control the use of their information. As such, another component of direct benefits included consideration of the future commercialization of the research and how those profits may or may not be shared by participants (Section 8: Commercialization).

Decision-Making

In a similar vein of athletes' empowerment to receive direct benefit from the research, decision-making was an especially important theme identified by nearly all of the participants. Most participants indicated that the athletes should be able to control both what samples and data they wish to contribute or withhold while still participating in the research studies and how their samples, data, and research results should be shared and used in the future. For example, most athletes wished to consent for future research (Section 9: Consent). Nearly all participants felt strongly that the athletes and their trusted stakeholders should be engaged in informing and developing research practices, and policies (Section 10: Engagement).

Major Recommendations

Below is a brief discussion of the recommendations as they relate to the study's findings followed by the most important recommendations that the author identified regarding both HPR

and biobanking policies and practices. These recommendations have been broken down into two target audiences: Alliance and Biobank Leadership and Human Performance Researchers.

Discussion of Recommendations Related to Study Findings

The most consistent finding was that it is vital that the Alliance empowers athletes and works in partnership with them to develop and implement this research agenda.

Vulnerabilities

There are a wide range of characteristics that impact athletes' willingness and ability to participate in research (Section 3: Athlete Characteristics). It is important that researchers understand these variabilities in resources and lived experiences when planning study designs, policies, and best practices. To ensure that research participation is equitable for a diverse group of elite performers, the Alliance will need to consider existing legal protections and their gaps as well as create policies and standards to ensure that the most vulnerable groups are protected and supported. To achieve this, the Alliance is encouraged to engage with a diverse group of aspiring and professional athletes along with multidisciplinary teams and stakeholders to inform research policies and procedures. Considerations include returning benefit to athletes for research participation including providing access to services throughout the Alliance (Section 3: Athlete Characteristics and Section 6: Disparities), personal results, study results (Section 7: Return of Results), implementing a community advisory board made-up of athletes and their trusted stakeholders (Section 10: Engagement).

Aspiring and professional athletes also have a much higher risk of re-identification and subsequent discrimination (Section 4: Confidentiality and Discrimination). Therefore, it is important that the Alliance proactively plan for higher security and data protection measures to minimize risks for this population. Potential protection measures include collecting only the

minimum necessary information to address a hypothesis, sharing only aggregated data, data perturbation to further mask identities, data/sample sharing embargoes, and/or restrictions on data and sample sharing to controversial third parties, such as teams or leagues. Although collecting the minimum data and samples necessary is contrary to the exploratory nature of biobanking, the Alliance could alter this recommendation to only share the minimum amount of data and samples necessary to address specific research questions, which may hinder studies that are more exploratory in nature. The Alliance should apply the highest standards of data and sample protections to all participants, and consulting with bioinformaticists, data scientists, and machine learning/artificial intelligence engineers to explore how data perturbation techniques may be implemented and adapted to varying research contexts would likely be the best way of ensuring confidentiality is preserved for all participants.

Research Effectiveness

Questions about the generalizability of research of elite athletes were raised along with concerns that the research may promote eugenics, lack practical utility for research participants (Section 5: Research Effectiveness), widen health disparities, and limit access of research by low-resourced researchers (Section 6: Disparities). Recommendations to address these concerns include creating policies that promote generalizability through representative recruitment, equitable access to research participation, incentives for oversampling of historically underrepresented populations, enhanced data protections for vulnerable and/or extremely small subgroups (Section 4: Confidentiality and Discrimination), restricting controversial data and sample usage, maximizing benefits to participants, and sharing of research materials with low-resourced researchers. The Alliance should have policies that require researchers to recruit representative samples and encourage oversampling of historically underrepresented populations.

The Alliance should also encourage and fund engagement of advisors from historically underrepresented populations to ensure policies and research practices are culturally appropriate, provide adequate protections, and return meaningful benefits to these communities (Section 10: Engagement). Similarly, the Alliance should consider hosting data and analysis tools online and offering access to multiomics and other resource-heavy laboratory testing to ensure low-resourced researchers have access to engage in high-quality research investigations. Finally, the Alliance needs to develop policies regarding uses of and best practices for research with sensitive information, such as genetic and mental health data. Policies should clearly outline both how this information may be used, prohibited uses, best practices for reporting results using race and ethnicity demographics, and explicit consequences for failures to abide by the policies should be included in internal and external contracts.

Return of Benefits

Research participation was viewed as a transactional process that includes direct benefit for participation. Similarly, altruism was offset by concerns that the research would help competitors more at the expense of participants. Returning individual- and study-level results in a meaningful way should be considered whenever possible (Section 7: Return of Results). Similarly, profit sharing in the commercialization of research discoveries was expected by some participants, and conflicting legal regulations may create conflict in the future (Section 8: Commercialization). The Alliance should explore the legal implications of commercialization activities using athletes' samples and data and should consider requiring a portion of any future commercial profits to be returned for future activities aimed at enhancing the health of the community. Many participants indicated that retired athletes lack adequate healthcare and there is a gap in the existing literature on how to best care for aging athletes. Therefore, requiring a

percentage of any commercial profits be returned to fund research on aging athletes' health would be a meaningful benefit to the athletic community.

Decision-Making

Across all findings, empowering athletes to be partners in the decision-making process was emphasized as being critical for the success of this research. One meaningful way to empower athletes in the decision-making process was to consider enhancing consent practices to allow individuals more control over the use of their samples and data (Section 9: Consent). Specifically, athletes may benefit from enrolling in one overarching study that allows them to choose what specific samples and data they wish to share for specific research purposes. Similarly, the Alliance should consider using dynamic consent, either opt-in or opt-out, to both notify and empower athletes to control how their samples and data are being used by future research studies and facilitate returning study-level results to athletes. Of note, journal articles should be included but are not sufficient to provide athletes with study results in an accessible and meaningful way. Another critical way of empowering athletes in the decision-making process is to engage them and their trusted stakeholders in informing research policies and practices (Section 10: Engagement).

The sections that follow in this document address these results in greater detail and provide more nuanced recommendations and discussions. Similarly, summaries of the major findings and recommendations can be found in the Summary Table at the end of this document. Recommendations that are anticipated to have low costs associated with implementation have been identified with an asterisk.

Top Recommendations for Alliance and Biobank Leadership

1. Utilize a wide variety of techniques to anonymize data, such as data perturbation, data aggregation, and data embargoes.
    a. Consider data and sample sharing embargoes for aspiring and professional athletes, including children, when individual data may be identifiable.*
    b. Engage bioinformaticists, data scientists, and/or machine learning/artificial intelligence engineers to inform anonymization best practices.
2. Create a policy to address restricting what kinds of data and results may be shared with teams, leagues, and regulatory bodies to minimize risk for discrimination for athletes.*
    a. Require Certificate of Confidentiality for biobank and all individual studies.*
    b. Examples include sharing only aggregated data and results, obtaining review and approval from players' associations, and/or not sharing individual data or results with any entity that has a commercial interest in athletes' performance.*
    c. Engage athletes and players' associations in decision making.
3. Engage and empower athletes to inform research policies and practices.
    a. Provide athletes with additional support resources, such as players' association representatives, non-affiliated and trusted medical staff, and researchers.
    b. Consider study-specific, dynamic consent for types of samples, data, and secondary research uses to improve autonomy, transparency, and standardization of Alliance policies and procedures across sites.
4. Establish a policy that defines acceptable and unacceptable uses of samples and data, particularly sensitive data such as mental health or genetic information.*
5. Establish policies that promote diverse recruitment and equitable return of benefits to participants.*

    a. Consider engaging diverse researchers, such as from Historically Black Colleges and Universities (HBCUs) and/or Hispanic Serving Institutions (HSIs), to ensure culturally appropriate research practices.

6. Establish a policy regarding commercial use of and commercialization from Alliance-funded samples and data.*
    a. Recommend considering requiring a percentage of profits to be used to fund future research, particularly research focused on the aging athlete.
    b. Consents should clearly outline what, if any, profit sharing will be available to participants or whether signing the consent is an acknowledgement of the transfer of ownership rights to the research team. If the latter, recommend highlighting this transfer of ownership by requesting participants initial that they understand this point.*
7. Obtain legal reviews to futureproof Alliance policies and practices.
    a. Data-sharing policies of organizations, such as universities, to understand what individual information may be shared publicly by the organizations athletes are affiliated with.
    b. Evaluate ownership rights across states and internationally, including an assessment of the applicability of name, image, likeness regulations on commercial endeavors that use individual athlete's information.
    c. Considerations for international research collaboration, such as with European Union and futureproofing for General Data Protection Regulation (GDPR).
8. Implement legal contracts that include restrictions on uses and penalties for violating approved uses and/or breaching confidentiality for external and internal researchers.*

9. Continue to conduct ethics assessments for other cohorts, such as military personnel and child athletes.
10. Consider hosting data and analytic tools on secure Cloud platform to facilitate future research by low-resourced researchers.
11. Consider restructuring human performance research to maximize benefits for participants and improve data and sample access for exploratory researchers unlikely to provide direct participant benefits.
    a. Consider one all-encompassing, human performance research study for participants to enroll into that includes all moonshots.*

Top Recommendations for Human Performance Researchers

1. Engage athletes to inform recruitment methods that capture diverse, representative samples (for the sport not only one site), potential benefits for research participation, and communication preferences for returning study results.
    a. Maximize direct benefits for research participation. This may require cross-site collaboration and rethinking what direct benefits may be.
        i. Whenever possible, provide participants with individual-level results.
        ii. Plan to share study-level results in an accessible way with participants, including secondary research results.
2. Consider study-specific, dynamic consent that allows athletes more control over what samples and data are collected and how they are used in the future.
    a. Ensure consents are clear about limitations in ability to anonymize data and potential for discrimination in playing time, hiring, future insurability, and contract negotiations.*

    b. If it is infeasible to offer dynamic consent for all secondary research, consider notifying athletes of research uses to improve transparency and build trust.
3. Avoid collaborations with authority figures, such as teams, without athletes and/or players' association guidance.*
    a. Consents should clearly indicate if individual-level data or results will be shared with any individuals or organizations who have power to make decisions about hiring and/or playing time.*
4. Emphasize confidentiality both internally and externally and determine what variables may be identifiable for athletes.
    a. Obtain a Certificate of Confidentiality for each study.*
    b. Consider having all research personnel sign non-disclosure agreements (NDAs) to minimize the likelihood of staff sharing participant information outside of the research setting.*
    c. Consider only reporting aggregated results and not using individual data points as high and low ranges as outliers have higher chance for re-identification.*
    d. Avoid sharing sensitive data in conjunction with more easily identifiable data, such as motion recordings or individual data points.*
5. Incorporate 'grit' and mental health assessments into research studies.
    a. Consider evaluating the mental toll research participation has on athletes.
    b. If returning individual level results, engage a multi-disciplinary team to support return of results to promote body-positive framing of information. Also, consider the potential impact results may have as an intervention on athletes' performance.

6. Plan for possible medical and mental health interventions when collecting data that could reveal health concerns or crisis.
7. Utilize research ethics consultations for studies using genetic, mental health, and/or other sensitive information.

The recommendations in the sections that follow in this document provide a wide range of considerations related to the topic and study's results.

Conclusions

Overall, this study found participants were interested in the research initiatives proposed by the Alliance, but the investment of time, energy, and privacy to participate in research needs to be balanced by athletes receiving direct benefits from research participation. The biggest risks identified were that professional and aspiring athletes have a much higher risk for re-identification and discrimination. To minimize these risks, the Alliance will need to go beyond traditional research de-identification methods to protect confidentiality. First and foremost, all studies, particularly the biobank, should obtain a Certificate of Confidentiality from the NIH to prevent researchers from being compelled to release participants' samples or data.

Athletes were also extremely interested to learn more about their bodies and performance, and they indicated that the biobank would be a useful tool to promote more research. However, athletes were interested in both controlling how their samples and data are used and shared as well as receiving information about what researchers learned by using their samples and data. Recent court rulings have reinforced athlete empowerment and concepts of ownership over their data, so the Alliance will need to be proactive in ensuring that future commercialization from athletes' data and samples is protected from litigation. One way the Alliance could promote discovery while returning commercial profits to the athletic community

would be to require a percentage of all profits be returned to fund research into aging athletes' health or research focused on addressing disparities. Finally, nearly all participants indicated that it would be critical for athletes and their trusted stakeholders to be empowered in the decision-making process and inform research practices and policies.

The major recommendations of this study are that the Alliance Leadership and individual researchers need to establish policies and procedures to protect against potential discrimination and promote confidentiality along with ensuring that their study samples are representative of the general population. Low-cost solutions, such as creation of Alliance-wide policies, acquisition of Certificates of Confidentiality, and enhancing existing contracts would be essential first steps in addressing the issues raised in this study. More complex issues such as the desire for athletes to obtain direct benefits from research participation may have low-cost solutions, such as providing biometric results from sample acquisition and quality control testing that may be informative to participants. Similarly, incorporating athletes into the decision-making process may require up-front costs, such as would be required to implement a dynamic consent method for secondary research, or cumulative costs associated with on-going direct engagement, such as hosting quarterly Community Advisory Boards. These costs are expected to be offset by the benefits of improving recruitment and retention by ensuring that all research is acceptable to athletes and research practices are based on athletes' best interests.

Athlete Characteristics

Background: Athlete Characteristics

Physical characteristics of elite/professional athletes are well described in the literature. There are also a growing number of studies focused on the mental health of athletes, including stress/mood, body-image disorders, and grit or mental fortitude. Similarly, more studies are emerging that examine athletes' behaviors are also readily available and are increasing with the availability of wearable technologies. However, few, if any, studies report on athletes' perspectives towards research participation. This lack of exploration may be due to the frequent use of secondary, "de-identified" data collected from athletes by organizations (e.g., universities, sports teams, and/or hospitals) during training and evaluation. In this scenario, athletes usually provide broad consent for data collection and sharing at the time of on-boarding.

Recommendations: Athlete Characteristics

Although elite performers share a common desire to maximize their performance and many are eager to learn more about their body's functions, the Alliance should create policies for recruitment and participant protections that take into account the wide variety of characteristics and circumstances athletes have throughout their journeys. At all stages of their careers, conflicts of interest, real or perceived, may unduly influence decisions to participate in research. Recommendations to ensure athletes are empowered to make independent decisions about research participation include avoiding team-based recruitment and/or ensuring staff recruiting participants are not affiliated with teams or authority figures who may be perceived as able to impact players' training, play time, scholarships and/or contracts.

Similarly, the Alliance should conduct a legal review of the regulations, and lack thereof, that are in place to protect athletes (such as enhanced protections against genetic discrimination)

as well as public health data sharing protocols for athletes, particularly college and professional. Protections are likely to vary by state and country, and the Alliance should adopt the most stringent protections as the best practices for research data collection, storage, and sharing (also related to Confidentiality and Discrimination Section). Similarly, as public data-sharing practices vary over the course of an athletes career, it is critical that the Alliance understands the variability in practices and designs policies and procedures to provide enhanced protections to all athletes, regardless of their current career stage (also related to Confidentiality and Discrimination Section). By proactively creating protective policies, the Alliance has the opportunity to ensure that all participants are provided with the highest level of protection regardless of their personal resources. Adopting an athlete-first model will likely improve the perceived trustworthiness of the Alliance as a whole, which is particularly important for professional athletes as the founders are team owners.

To further an athlete-first agenda, the Alliance is encouraged to engage a diverse group of athletes to assist in developing best practices for research practices (also related to Engagement Section), including but not limited to consent development and practices (Consent Section), study design considerations (also related to Research Effectiveness Section and Disparities Section), and sample and data sharing restrictions (also related to Confidentiality and Discrimination Section). Furthermore, athletes should be engaged about when and how research can provide direct benefits to participants (also related to Return of Results Section and Commercialization Section) to ensure that solutions are meaningful and acceptable to the participants. It is anticipated that compromises will be required, but studies have shown that research that is community-informed has better recruitment and sustainability outcomes and can improve research effectiveness outcomes.[26]

Due to variable resources (also related to Disparities Section), the Alliance should also consider creating policies that account for athletes' ability to take time off from training, travel to the research facility, and any potential financial costs associated with adverse outcomes. These financial burdens will likely impact athletes competing in individual sports and athletes with less financial security (also related to Disparities Section) more significantly than those on team sports where they have more time off, stable income, and healthcare via their team contracts. Similarly, the Alliance may want to consider equitable access to research to ensure the studies are diverse and generalizable (also related to Research Effectiveness Section and Disparities Section).

Other resource-related considerations include sharing resources across the Alliance for all participants, such as including free and/or discounted access to ancillary and/or partner services as a form of direct benefit and means of promoting individual performance for under-resourced participants (see Disparities Section for more discussion). The Alliance could consider leveraging their collective knowledge of best practices and provide all participants with educational materials related to rest, recovery, nutrition, and other performance-related sciences. Similarly, participants may benefit from scientific assessments of commercial products that have little to no evidence of effectiveness and/or a guide for how athletes can "get the biggest bang for their buck" with training, nutrition, and recovery. Shared resources may include access to Sports Psychologists, Nutritionists, or other service providers that can function remotely. Adding value by leveraging partner relationships may address athletes' desire to gain access to services that they may otherwise not be able to afford when research studies are unable to return individual results (Disparities Section, Return of Results Section, and Commercialization Section have related discussions). Such services may include personal training assessments, membership to

training facilities, career planning services, access to scouting staff for private consultation, or legal services for contract reviews. Other ancillary support may include increased incentives and/or reimbursements for participants with lower resources, conducting on-site research to alleviate the burden of travel, and consideration for free or discounted treatments or products that result from the Alliance's research (see Commercialization Section for more discussion).

Another consideration for how the Alliance can facilitate an athlete-first agenda is to utilize a wide variety of disciplines to inform standardized data collection, storage, and sharing. The Alliance should also plan for additional support related to types of information collected. For example, if all athletes are going to be asked about mental health status or health conditions, then the Alliance should have policies in place to intervene clinically if necessary. Such cases may include plans for mental health professionals to rapidly assess any athletes who report suicidal ideation or providing a multidisciplinary action plan if eating disorders are identified. This health information should be classified as extremely sensitive and sharing of this information with institutions that athletes are affiliated with, such as employers, should be restricted (see Confidentiality and Discrimination Section for more discussion). Furthermore, the Alliance should have a policy regarding how any clinical interventions and assessments will or will not be separated from the research records in these events, how such information should or should not be shared with secondary researchers, and standardized language in consent documents related to services, costs, and data collection and sharing in the event of clinical intervention.

As many athletes voiced concerns about conducting HPR with child athletes, the Alliance should establish criteria for when research on minors is scientifically justified and ethically appropriate in collaboration with seasoned athletes. Furthermore, the Alliance should provide

guidance for researchers about appropriate protections for that population may be necessary. For example, athletes felt that such research participation would put undue pressure on children and may lead parents to raise their expectations for the child to become a professional. Therefore, mental well-being evaluations and interventions may be appropriate protections to add into any research protocols that include minors. As child athletes were not the focus of this study, we recommend future research be conducted on this and other higher risk groups.

This The Alliance has an opportunity to work with a wide variety of elite athletes, but the needs and concerns of athletes are expected to vary. To ensure that the research practices and policies of the Alliance promote HPR for all elite performers, the Alliance should consider similar research as this for other cohorts to determine what context-specific barriers may exist. For example, although most athletes spoke about assessment fatigue, the feedback about Olympic sports indicates that Olympians may be at a much higher risk for negative outcomes related to additional evaluations that do not provide direct benefits to them (also related to Return of Results Section). Other cohorts that have unique risk-benefit profiles are active military personnel, child athletes, and unique subgroups, such as perinatal athletes, trans athletes, and other groups historically marginalized and/or underrepresented in research. Furthermore, the Alliance should work with these athletes and their existing support infrastructure, such as players' associations, to design research policies that protect all participants as other cohorts are likely to have less support infrastructure available to them at the time of recruitment.

Awareness of the variability in support infrastructures amongst elite athletes is critical for developing equitable research policies and procedures. Policies and procedures should promote diverse research participation while maximizing protections for research participants across all stages of their life. As such, athletes who lack robust support infrastructures may be most

vulnerable and thus could benefit the most from the Alliance proactively addressing barriers and misconceptions. Many of these recommendations are discussed further in the following sections but include enhanced protections against confidentiality and limitations on who has access to the athletes' data and research results (Confidentiality and Discrimination Section), policies that promote equity and diversity in recruitment (Disparities Section), identifying means to return benefits directly to participants (Return of Results Section and Commercialization Section), enhanced consent processes (Consent Section), and inclusion of athletes and their trusted advisors in the decision-making process (Engagement Section).

Confidentiality and Discrimination

Background: Confidentiality and Discrimination

Concepts like privacy, confidentiality, and discrimination have been well documented in the Precision Medicine literature.[137,240,267-269] The Genetic Information Non-discrimination Act (GINA), a federal regulation, prohibits the use of genetic information to determine health insurance coverage or employment, with some limitations and exclusions.[270] Most states have their own stricter versions of this protection. However, GINA has not been well-established through the court system, and it is unclear what, if any, protections athletes can reasonably expect without enhanced protections via collective bargaining.[114] Furthermore, athletes have routinely had rights afforded by the Americans with Disabilities Act (ADA) violated, so it the ability of existing laws to protect athletes against discrimination are questionable at this time.[114,246,247] It is also well-established in the rare disease community that rare the phenotypes have a greater the chance that one's identity can be discovered.[150,271] However, general demographic data can also be used to identify individuals within the general population as

well.[252] Privacy issues need to be reconciled with health and existing professional disparities prior to data sharing to prevent potential privacy disparities.[114,272]

Although professional athletes are not generally thought of as being vulnerable, many characteristics of this population make them especially vulnerable to traditional research practices.[114] In particular, professional athletes may be more vulnerable to traditional research "de-identification" methods, broad sample and data sharing, risks of adverse events, and risks for discrimination. Athletes' have been previously identified as at a higher risk for re-identification, surreptitious collection and use of genetic information, and discrimination due to their celebrity-status and often large salaries.[2,7,16,17,99,273] Increased risks for discrimination and exclusionary practices in sports have been described in the literature with respect to enhanced screening and genetic testing.[7,92,114] This study, however, explores how research activities may also increase risks for athletes.

Recommendations: Confidentiality and Discrimination

The Alliance should consider going beyond traditional research best-practices to create policies and procedures for handling the health information and biological samples from elite athletes. To this end and incorporating recommendations made by interviewees, the following recommendations are intended to address confidentiality, including re-identification, and discrimination concerns.

Enhanced Protections for Confidentiality

The nature of Precision Health research requires researchers to identify and collect the unique individual characteristics associated with elite performance. Coupled with the relatively small number of elite performance compared to the entire population, many data types and combinations may be readily identifiable.[151] Therefore, the Alliance should consider expanding

the definition for “identifiable information” to include a wide variety of phenotypic data. The research team should be particularly mindful of phenotypic data that is likely to be in the public domain. Maximizing confidentiality protections is expected to improve research recruitment and sustainability, the latter would be most impacted by breaches in confidentiality. The main way to minimize risk for participants would be for all studies to obtain a Certificate of Confidentiality from the NIH. The Alliance should include its policies and procedures to protect confidentiality and any foreseeable limitations in both their consents and all public-facing platforms (additional discussion in Consent Section). Limitations should be clear and specific, and the potential consequences of re-identification, such as employment discrimination, should be included as a known risk in the consent forms (additional discussion in Consent Section).

Enhanced protections that the Alliance should also consider include only sharing aggregated data. Even when sharing only aggregated data, the Alliance should be cautious to not use individual data points as high and low values because these outliers are likely to be the most identifiable. Similarly, aggregated data sharing for extremely small subgroups should be treated similar to sharing of individual-level data. This is particularly important for athletes in marginalized groups, such as transgender athletes (additional discussion in Disparities Section). All athletes, particularly those smaller subgroups, should be provided clear explanations in the consent that despite sharing only aggregated data, the risk for re-identification is still possible. For these high-risk groups, the Alliance should consider obtaining separate consent for biobanking and public reporting of study results (also related to discussions in Disparities Section and Consent Section). Similarly, the Alliance should consider creating an internal review process to assess potentially identifiable data at an individual level. In the case of Precision Medicine, these types of reviews would be conducted of patients with extremely rare diseases. In

these cases, the diagnoses, location of treatment, age, and sex may all be considered identifiable data due to the rarity of a condition. The same principles are likely to apply for athletes who have unique features or co-morbidities that are rare to the athlete community, such as arrythmias or genetic conditions. The Alliance should apply strict scrutiny to issues related to confidentiality and identifiability in the data storage and sharing policies. Increased protections that prioritize confidentiality, however, may negatively impact Precision Health researchers' ability to fully utilize the data for exploratory research purposes. Therefore, engaging athletes in the decision-making process with other stakeholders, including the researchers, is expected to be critical to ensuring that policies are acceptable to all parties (see Engagement Section for more information).

Another method for minimizing risks of sharing identifiable information would be to only collect the minimal amount of information necessary to conduct high quality research. The Alliance should consider requiring hypothesis-driven data collection and sharing, particularly for highly sensitive or high re-identification risk data. Notably, this research method is frequently at-odds with the discovery process inherent in Precision Health research. Therefore, when the principle of minimum-necessary is unable to be applied, the researchers should consider data perturbation to make re-identification less likely. Data perturbation, or the systematic introduction of 'white noise' into the datasets, makes individual re-identification much more difficult. When done systematically, the original data can be accessed as needed by those in control of the algorithm specifications. Additional research may be required to ensure that data perturbation efforts do not conflict or confound research needs and results. Hypothesis-specific perturbation may be a solution to this problem, but additional research into this solution should be explored in collaboration with computer science engineers and/or bioinformaticists.

Another practice the Alliance can consider, either in conjunction with the above or applied universally, would be data and sample sharing embargoes. These embargoes could be for a specific amount of time, such as two years for professionals and longer for college students depending on current level, or until an athlete has finished competitive sports. This policy would reduce the risks for discrimination as well as address concerns that athletes' research participation would likely only help up-and-coming athletes to ultimately replace participants sooner.

Sensitive Data

Some types of data, such as genetic and mental health information, were generally considered to be more sensitive. Additional policies and procedures should be considered to ensure responsible storage and sharing of these types of information. Readily identifiable data, such as video or detailed, individual phenotypic information should be securely stored separately from more sensitive data, including all biological samples. Such storage practices may require unique participant IDs for different types of information and samples. The Alliance could institute a unique global ID that is used for sharing purposes. By separating these datasets and adding an extra layer of de-identification, a data breach of one system or the other is less likely to result in the re-identification of sensitive information as only the master list of research IDs to universal IDs would link this information, which should be stored using the highest data encryption methods. As all samples contain DNA, which is considered sensitive data by participants, the Alliance should create policies regarding what types of genetic research uses are considered acceptable and unacceptable (additional discussion in Disparities Section).

Studies that include movement imaging, videos, and/or simulations, even if participant features are removed, should consider creating guidelines and policies for when this type of

information may be considered identifiable. Athletes with unique techniques, body proportions, or other rare traits captured by imaging will be at much higher risk for re-identification. Similarly, the sharing of video or detailed individual phenotypic data extracted from imaging along with biological samples, genomic or mental health data, or other sensitive health information may require differential access regulations. Athlete engagement in this discussion is highly encouraged (see Engagement Section). Consents should disclose risks for re-identification and how these identifiable images will be securely stored, if they may be made public, and conditions where these images may be shared with potentially sensitive data (additional discussion in Consent Section). Furthermore, the Alliance should consider requiring individual consent for any genetic research and/or research using sensitive data (see Consent Section).

The Alliance should also consider whether omics-related data extraction from samples should be restricted to the Alliance's biobank or other in-house researchers. Preventing external researchers from extracting omics data would decrease the likelihood external researchers would share sensitive data to unaffiliated third parties. Such a practice could also decrease the risks of widening disparities as under-resourced researchers who lack access to sequencing technologies could have equitable access to the data via the biobank (see Disparities Section for additional discussion and recommendations).

Legal Considerations

Another facet of enhanced protections against the misuse of an individual or groups' data is that such an event could have devastating consequences to the integrity of the Alliance as a whole. Just as the athletes' samples and data have greater intrinsic value outside of research, the stakes for the Alliance may be equally tenuous as negative publicity will also have a wider reach and deeper impact. To further help ensure that samples and data are adequately protected from

misuse and intentional re-identification, the Alliance should be requiring all employees, institutions, and any party with access to individual-level data to enter into a contractual agreement that specifies that any attempts to re-identify individuals or share identifiable individual information, including verbal sharing of the identity of one or more research participant, will face strong punitive recourse for contract violations. The Alliance should consider utilizing enhanced Material Transfer Agreements and Data Use Agreements that include the explicit, approved purpose for the sample and/or data uses, a list of unacceptable uses, and direct consequences to the researchers who violate these contracts. Included in these contracts, external researchers should be explicitly forbidden from sharing data and samples to third-party researchers. In the event an external researcher wishes to share samples and data beyond their lab, new contracts should be generated through the Alliance's biobank. This enhancement will improve tracking of sample and data usage, allow for the complete destruction of samples and data upon participant request to withdraw from research, facilitate the potential for future return of individual- and/or study-level data to participants, and minimize the risk that the Alliance will be viewed as responsible for any abuses of the shared samples and data. Similarly, due to the increased public value of the athletes' identity and research information, all staff and students who have access to research data, particularly identifying information, should be required to sign Non-Disclosure Agreements that again include penalties for breach of the contract. This practice will help dissuade employees from leaking information outside of the research team.

Legal consultation may also need to be engaged to identify potential hazards and means for protecting against risks to participants. A landscape analysis of current institutional information sharing policies and practices should be conducted. Furthermore, an assessment of

the potential impact of publicly available data should be considered in the Alliance's policies for both data sharing and result reporting. Specifically, the policy should address when and if individual-level data and results may be made public and what factors are used to determine the confidentiality risks.

Discrimination

The biggest concern about HPR biobanking was teams, including universities, having access to athletes' research data and results. The Alliance should consider creating policies that place limitations on data sharing and access that ensure that teams, leagues, sponsors, and other parties who may impact athletes' financial well-being are unable to access data and/or individual results. Sharing of individual data, samples, and research results with employers, schools, and potential sponsors should also be discouraged if not banned to provide additional protections to athletes. Due to the fluidity of athletes between organizations and institutions, it is recommended that players' associations be involved in the negotiation process of data and sample sharing agreements with institutions that employ and/or financially support athletes (additional discussion in Engagement Section) as well as considering the appropriateness of employing data sharing embargoes to protect athletes from discrimination. Finally, the Alliance should also consider creating a policy, if it has not already done so, that addresses how individual data and results may or may not be accessed by the donors and their affiliates. These policies should be included in all Alliance-related research consents and all public-facing outlets.

The Alliance should also consider obtaining a Certificate of Confidentiality to protect participants from having their data and samples accessed surreptitiously. The limitations of the Alliance's ability to protect samples and data from subpoenas should be clearly stated in the consent and all public-facing outlets.

Lastly, the Alliance should consider conducting a legal review of what, if any, obligation aspiring or professional athletes would have to disclose any research results. Return of Results Section discusses the desire for participants to receive individual research results further. However, it is important for Alliance researchers to understand what, if any, potential ramifications providing athletes with personal results may have. It should be noted that returning results to athletes may occur in less formal processes than discussed in the Return of Results Section. For example, researchers may informally discuss findings during data collection and relay to the participant that what they are seeing could result in a specific injury. If that information may be used against athletes in future insurance claims, it is necessary to disclose to athletes in the consent process that risk.

In summary, sharing individual level data should be considered high-risk, and thus, should be avoided whenever possible. Similarly, these risks are increased significantly for smaller subgroups, such as transgender athletes, athletes with unique characteristics, and athletes competing perinatally. Again, all policies, procedures, and protections adopted by the Alliance should be shared publicly to improve transparency and build trust with the community. Similarly, these efforts and their limitations should be clearly outlined in consents, and any known potential risks should specifically identified along with the possible consequences, such as impact on future employment and/or insurance.

Impact of Research

Background: Precision Health Research Impact

Due to the statistical requirements for large, homogeneous samples, many Precision Health studies have failed to equitably recruit and/or study diverse populations resulting in an inability to generalize findings to the general population.[43,152,197,274] The field of Sports Genomics

discusses the need for power, replication, and validation of genome-wide association studies and the risks associated with returning inaccurate study results.[2,7,113] However, as Precision Health moves away from disease states to states of health, new issues about the effectiveness of the research arise.

One known issue about measuring performance is the concept of grit, a concept made popular by Angela Duckworth.[275] The concept of grit has many names in sports: mental health, psychological resilience, psychological preparation, and mental toughness.[276-281] It can also include concepts of mindfulness and somatic awareness/somaesthetics.[282,283] The antithesis of these concepts includes phrases like "choking" and can manifest physically as "the yips," which manifest through social sources, anxiety, and perfectionism.[284-286] These concepts include various interventions, such as psychotherapy, somatic awareness training, mindfulness practices, breathing techniques. The physical effects of grit-related interventions include heartrate variability, respiratory sinus arrhythmia, increase in alpha waves and decreases of theta power in brain function, increased activity in the cortical and subcortical structures, lowering hypertension, and may have small effects on biomarkers.[287-289] However, the ability to measure grit continues to confound the field.[281] Other outcomes include improvements in anxiety, depression, sleep disorders, and perceptions of pain.[288] It is also worth noting that researchers have also been exploring the effects of team dynamics on sports performance.[290,291]

Recommendations: Impact of Research

The Disparities Section and Confidentiality and Discrimination Section touch on some of the related potential pitfalls of how the Alliance's research may be harmful if the Alliance does not proactively ensure equitable recruitment and enhanced confidentiality protections early in the research process. Another concern raised in the interviews was the generalizability of studying

elite performers as a lifetime of physical training may confound attempts to generalize findings to more sedentary cohorts. To this end, the Alliance should consider creating policies that establish criteria for generalizability that include standards for evaluating and methods to improve the generalizability of research results. For example, research generalizability may benefit from an assessment of how the physiological process observed in an elite athlete's samples and data could be leveraged in the future to improve the health of less physically active members of society. A policy requiring research proposals to evaluate this criteria could improve the allocation of funding to prioritize studies most likely to be generalizable and would enhance the study's ability to communicate the meaningfulness of the research to the participants (see Consent Section and Engagement Section for related discussions). A similar criterion may be used for sample and data allocation for secondary research uses that prioritizes maximal generalizability. This consideration also relates into the potential commercialization of research findings and whether claims of potential future benefits are reasonable or appropriate outside of elite performers (see the Commercialization Section and Disparities Section for related discussions).

The effectiveness of only measuring physical aspects of performance was also called into question by many athletes who pointed to grit as what truly distinguished elite athletes from recreational or amateur athletes. The impact of mental well-being interventions such as breathing techniques could reasonably have physiological impacts that if not measured may confound results. Similarly, the ability to overcome adversity may directly relate to one's ability to train effectively, recovery from injury, or return to competition after life-changing events, such as childbirth. Therefore, the Alliance should consider standardized measures for capturing grit-related concepts and mental health factors and interventions as standardized demographic and

phenotypic data collection. Development of appropriate measures for these factors should include athletes as mental health information was described as sensitive data (Confidentiality and Discrimination Section) and the appropriateness of such data collection is best determined in collaboration with the athletes (related discussion in Engagement Section). Similarly, the Alliance should include appropriate mental health specialists to inform the potential for clinical intervention, appropriateness of data being collected, and evaluation of psychometric qualities of proposed measures (related discussion in Athlete Characteristics Section).

Another concern raised about the effectiveness of the research was the potential for how returning results (directly relates to Return of Results Section) may directly impact the athlete's performance, either positively or negatively. Therefore, measuring mental well-being before and after any return of information during a study would be important to assessing both the impact of the information on the athlete's mental health as well as understanding the potential impact on an individual's performance. One hypothetical example is that the digital twin study informs an athlete during the course of their study that they are rotating in such a way that a joint is at an increased risk of injury. This information is unlikely to impact their mental well-being, but the athlete may try to change their movement to avoid injury. The change in movement may negatively (or positively) impact the performance measure outcome. Alternatively, a hypothetical scenario that returns injury risk scores to athletes may have negative mental health implications for athletes with high risks of injury, particularly if no actionable information is provided with this score. This negative mental state is also anticipated to impact overall physical performance outcomes. The Alliance should have policies and best practices for studies that return results that should include evaluations of the impact of the results on mental well-being, behavior/training adaptations, and physical performance.

Finally, the scientific process itself was identified as a barrier to both athletes and non-athlete stakeholders. Generally speaking, research effectiveness from the non-scientific participants was generally defined as the research's ability to be meaningful and useful, either directly improving performance or providing meaningful information to participants. Return of Results Section discusses the perceived need for direct benefit to the athletes in greater detail. However, for the purposes of discussing research effectiveness, the scientific process itself was understood to be a barrier to providing timely, useful feedback, either at the study- or individual-level. Furthermore, many of the bench-science studies due to their exploratory nature reasonably may not generate findings that are meaningful outside of the scientific community. However, these studies may struggle to recruit participants due to this lack of direct benefit. These considerations are typically why biobanks are the gold standard for exploratory, bench research studies. However, many of the Alliance's moonshots were viewed as either unlikely to result in benefit outside of the scientific community or would only be deemed acceptable for an athlete to participate when the scientific evidence is nearing clinical intervention thresholds. The Alliance should consider enrolling all participants into one overarching study that encompasses all moonshots and innovation hub projects to improve recruitment for studies that lack direct benefit and maximize the perceived impact of the research for participants (also related to Return of Results Section). This unified study would give participants a higher likelihood of receiving meaningful results as well as providing a larger pool of participants for exploratory studies whose work may be too early in the scientific process to be reasonably expected to produce meaningful results to participants.

Disparities

Background: Disparities in Precision Health Research

As mentioned in Research Effectiveness Section, Precision Health research struggles to be generalizable primarily due to the research being most acceptable and accessible to wealthy, well-educated, non-Hispanic White people.[43,152,154,292] This lack of diversity in the research samples limits its generalizability and therefore widens existing health disparities.[154,155,191,293-295] Furthermore, Precision Medicine has only recently begun to reconcile with its role in eugenics and fostering of false notions of biological basis of race.[296-300] Sports in general also have a long history of racism and reinforcement of white supremacy.[301-303] Precision health research will need to be proactive in its efforts to not reinforce disparities or promote eugenics as it moves from studying disease states to studying states of extreme health.

Borrowing from experiences in genomics research, researchers reported a lack of evidence to support sexuality being associated with a single gene or a few genes.[304] Despite their efforts to limit misinterpretation of their findings, the study was used by a third party to promote a "How Gay Are You?" genetic test, which was eventually removed due to public and scientific critisisms.[305] This research is one example of how well-meaning researchers may enable external parties to commercialize and weaponize research findings for profit and/or discriminatory purposes.

Global disparities in available resources for researchers have also been described in the Precision Medicine literature, and the recommendations include providing cloud-based access for analysis by under-resourced researchers.[306,307] Specifically, researchers in low- and middle-income countries (LMIC) lack reliable internet, large, secure data storage, and access to multiomics sequencing technologies.[306] The partnership described by the Alliance with

UNESCO will need to build equity into data and sample sharing to promote access and improve health outcomes at a global scale.[5]

Recommendations: Disparities

As Precision Medicine transitions to Precision Health research, there is a need for proactive emphasis on equity and justice to avoid widening existing health disparities. To this end, the Alliance should consider creating policies to guide the standards and requirements for researchers regarding recruitment, research design, and accessibility of benefits generated by the research. A minimum standard would be to require research studies funded by the Alliance to recruit representative samples from the sport(s) as a whole, not just the local site. Oversampling of historically underrepresented groups is recommended to ensure that the body of work is in fact generalizable to the population. However, the Alliance should be mindful of cultural differences and past research abuses when seeking diverse participants, so including a wide range of voices and lived experiences in the decision-making process and policy development would be important for ensuring that the policies and practices of the Alliance are inclusive and equitable (also see the Engagement Section).[308] Due to the lack of diversity within this study's sample, additional research is recommended to ensure that opinions of athletes of different ethnicities and races, those with lower educational attainment, and cohorts of elite performers not represented in this study should be explored and addressed.

Furthermore, the Alliance should examine subgroups within professional sports to determine what characteristics are not well represented and the impact of recruitment on re-identification (see Confidentiality and Discrimination Section for additional details). For example, the number of indigenous athletes in professional sports is very small, but failure to include a wide range of ancestries may limit the ability of this research to be generalized.

However, the smaller numbers in the population will likely increase the risk for re-identification (see Confidentiality and Discrimination Section for additional details). The Alliance should develop policies and best practices to address health disparities and promote health equity.

When striving to include historically underrepresented and marginalized communities, historic research abuses, distrust, and risks for further stigmatization should not be overlooked.[45,48,51,60] Including genetic information with human performance data risks having socially constructed stereotypes of race being reinforced and/or weaponized against communities.[59,296,300] Several participants alluded to HPR being aligned with eugenics. Furthermore, eugenics, racism, sexism, and sports continue to intersect, so it is critical that researchers make active efforts to avoid perpetuating stereotypes, narratives of biological basis for race or ethnicity, and on-going disenfranchisement at the elite level. As recommended in the Confidentiality and Discrimination Section, the Alliance should create a policy that specifies how genetic information can and cannot be used and should also include guidelines for how and when race, ethnicity, or ancestry should be reported in genetic studies. Concerns that the research may be used to exclude individuals from competition due to a perceived lack of genetic ability, multiomics findings, or other immutable factors should be addressed early in the Alliance's formation. Similar to the need for policies to prevent the misuse of race and ethnicity in performance research, the Alliance should have policies that guide researchers in how information is reported to mitigate downstream and/or third-party misuse of findings for discriminatory practices (see Confidentiality and Discrimination Section for additional details). As misuse of Alliance research threatens the sustainability of the research, legal consultation is also recommended to ensure that all contracts and preventative measures are taken in advance of misuse.

Providing educational training and resources related to the ethical, legal, and social implications of Precision Health research for researchers may help the Alliance improve study designs and research practices to be more culturally appropriate and meaningful than past research efforts. Similarly, the Alliance should provide access to research ethics consultations to provide trained evaluation and recommendations for research studies that may be more controversial or are struggling to recruit diverse participants, particularly for studies exploring the genetic underpinnings of performance.

The Alliance should have clear policies in place to ensure that any genetic research does not inadvertently adopt a eugenics tone or promote racist stereotypes. To this end, the Alliance should identify key demographic information upstream of social constructs of race and ethnicity that can be used to evaluate the role the environment and structural racism may have on variations observed amongst athletes.[296] Enhanced demographics may include zip codes, the Everyday Discrimination Scale, environmental factors/exposures, and/or Adverse Childhood Events measure.[296,309-311] Utilizing other validated and evidence-based measures from the PhenX Toolbox is also recommended to ensure appropriate, meaningful, and standardized phenotypic data is collected.[312,313] Traditional social constructs of race and ethnicity are appropriate for assessing health disparities and should be used for evaluating equitable access and inclusion in this research.[296] These recommendations align with the National Academies of Science, Engineering, and Medicine's recent recommendations for how race and ethnicity should be responsibly used in genetics and genomics research.[296] A final recommendation to promote culturally appropriate and meaningful research for historically marginalized and/or underrepresented communities would be to encourage researchers from diverse backgrounds,

particularly those who are members of said communities themselves, to conduct research within the Alliance. This could be in the form of diversity grants and/or supplements.

At a local and national level, concern was raised that many people in the country are deprived of access to new innovations and targeting elite performers would further remove a large portion of the population from this research. This coupled with the intention of this research to be generalized to all members of the public raised concerns that a lifetime of training is simply never going to be generalizable (see Research Effectiveness Section for discussion). Participants suggested engaging communities without access to sport, groups that are marginalized within the community, and those at higher risk for diseases that physical activity could offset would be not only beneficial to those historically left out of innovation, but it would add more meaning to research participation for the athletes. This suggestion also helps to offset the concerns from the Athlete Characteristics Section that the Alliance's research will merely help the rich get richer by providing products that will be cost-prohibitive to most athletes and the public.

The risk for widening health disparities extended as well to discussions of the Alliance's partnership with UNESCO and stated intentions of making the samples and data available to researchers throughout the world. Several participants remarked that under-resourced countries and researchers would likely lack the technology, personnel, and multidisciplinary expertise to conduct high-quality research if equal access to samples and data are all that is being provided. Suggestions to address this include planning ahead for equitable access by acknowledging that many low- and middle-income countries (LMIC) lack stable, high-speed internet, and specialty services, such as multidisciplinary training teams. The Alliance should consider building into its research design and infrastructure methods that can facilitate equitable research without

furthering the divide between wealthy, well-resourced countries and researchers and those in LMIC. One example to consider would be to host data and analysis tools on cloud-based, secure servers, which would remove the need to download and store large datasets.[307] Another consideration would be to conduct all omics sequencing via the Alliance's biobank to ensure that researchers without access to sequencers, big-data storage, and funding to conduct complex multiomics sequencing can access the data and analysis tools virtually. In-house sequencing would also enhance the Alliance's control over the sharing of sensitive genetic information as discussed in the Confidentiality and Discrimination Section.

Building in equity and resource-sharing into the Alliance's policies and practices can also be extended to improving the research participants' experiences. As many studies are likely to lack direct benefit for participants, providing participants with access to specialty services, appropriate reimbursements, and educational resources, the Alliance can ensure that research participation is not limited only to those with the most resources and establish a mutually beneficial relationship with athletes (see Athlete Characteristics Section for additional recommendations).

Finally, the Alliance should consider partnering with both regulatory bodies and athletes who have faced discrimination to ensure that the proposed research studies take into consideration the wide range of factors, such as ancestral heritability and the non-binary medical classification of sex.[314,315] In addition to partnerships within the communities, the Alliance should include bioethicists in the scientific review process. Other considerations include emphasizing research in under-researched fields, such as the perinatal period, and working with regulatory bodies to improve access to sports by driving data-driven decisions for participation standards.

As with recommendations from other sections, all policies should be made publicly available and included in consent documents as relevant.

Return of Results

Background: Return of Results

The expectation to receive personal benefit from research is not new, and it is particularly important when recruiting racialized and marginalized members of the community.[226,308] Similarly, the concept of therapeutic misconception speaks to the frequency of research participants to believe research participation will directly benefit them, including non-clinical research such as biobanking.[226,228,316,317] Discussions about the appropriateness of returning research results, either study- or individual-level, gained traction with genetic and genomics research as this field began to blur the lines between clinical and research.[137,318] As Precision Medicine research straddles the clinical and research domain, the utility of research results is regularly discussed and debated.[43,51,62,110,236,319] The ability to validate and test utility of Precision Medicine results has led to a growth in this practice, but research results with uncertain pathogenicity are less commonly returned.[62,89,243,244,320,321] Studies have shown that returning research results for health-related genetic conditions significantly impacts willingness to participate in research, which included variability by race and ethnicity.[103] This debate is likely to be renewed with advances in studying states of health, but the feasibility and appropriateness of returning individual-level research results for sports performance will depend on the validity of the result and its utility.[2] Similarly, the need researchers to rethink what population-level benefits may mean beyond altruistic improvement of general scientific knowledge is also rising in popularity.[56,308] Altruism for research participation may need to be more directly focused on the community served by the research rather than the scientific value generated from the

research.[308] Furthermore, the competitive nature of sports has yet to be factored into discussions about returning research results to participants nor has its effect on altruism as a motivation for participation.

Recommendations: Return of Results

Individual Results

As athletes and non-athlete stakeholders typically share the view that research participation should provide direct benefits to participants, it is recommended that the Alliance create policies and best practices for what, if any, individual-level results may be returned, how results will be validated, what infrastructure and support is available for the return of results process, and assess alternative benefits in cases where results are not available. The process of deciding what information could be returned to athletes should include athletes and other stakeholders to ensure that any limitations regarding reliability or risks related to receiving results are clearly explained both in the consent and at the time results are returned. The Alliance should also consult with legal experts regarding whether athletes' have a duty to disclose research results.

The Alliance should prepare for the event that research data will reveal medically actionable health problems, including mental health (see Athlete Characteristics Section for additional discussion). Studies should have shared language on whether medically relevant health information will be made available to participations, how clinical treatments will or will not be billed, the process by which this information may be shared with athletes and medical personnel, and whether clinical interventions and health information will be shared with other researchers. The Alliance should consider a multi-disciplinary team that includes mental health providers to review and plan for returning medically actionable health conditions to ensure all

participants have access to relevant health information and services. Similarly, athletes should be provided with access to physicians and/or other relevant healthcare staff (such as genetic counsellors) who has no stated relationships to the institution(s) the athlete is affiliated with, both school and employer (see Confidentiality and Discrimination Section for more discussion). This information disclosure may impact the athlete's future career and/or insurability through their employers (see Confidentiality and Discrimination Section for more discussion). Participants should be offered the ability to consent to receiving such information or should be informed of what types of information the researchers feel morally obligated to return regardless of individual consent, such as life-threatening findings (see Consent Section). However, the decision to share these results with teams or employers should be the athlete's decision and all efforts should be made by Alliance researchers to avoid releasing said information without the athlete's signed authorization (related discussions in Confidentiality and Discrimination Section, Consent Section, and Engagement Section). Finally, as previously discussed, the

As discussed in Research Effectiveness Section, studies limited to improving scientific understanding and generalizable knowledge would benefit from partnering with studies that return individual results to both facilitate recruitment and enhance the meaningfulness of participation for athletes. Again, the Alliance should also consider enrolling all participants in one all-encompassing study that would allow athletes to receive direct benefits from some studies and provide other bench research studies access to athletes despite being unable to return individual results. Such an enrollment method is anticipated to make research participation more impactful for both the participants by maximizing the personal utility of participation and for the researchers to maximize access to more useful data. Logistically, in addition to having a systematic return of results, a universal protocol would improve the consistency of consents

(Consent Section), data and sample collection and sharing (Confidentiality and Discrimination Section), and participant follow-up, including return of study-level results. This practice could increase the opportunity to scavenge clinically obtained samples longitudinally and thus minimize the need for participants to have invasive sample collection(s). Furthermore, a universal protocol would also allow athletes to access all resources available through the Alliance (Athlete Characteristics Section and Disparities Section). Adaptations to how this recommendation could be implemented via the consent process are also discussed in the recommendations for Consent Section.

In the event that individual-level results are not possible, the Alliance should consider what other meaningful benefits could be shared with participants (see Athlete Characteristics Section, Disparities Section, and Commercialization Section for additional recommendations). Such direct personal benefits may include personal evaluations, biometric assessments, access to training facilities and/or performance coaches, access to affiliated partners' resources, access to mental health services, or other forms of incentives that could aid in improving their performance. The Alliance should also consider what community-level benefits may be meaningful to participants, such as extending research recruitment to include high-risk, marginalized populations (also see Disparities Section), funding research that is impactful to either the community at-large, subgroups within the community, and/or retired athlete health as this was reported as a largely neglected but important issue (also see Commercialization Section).

Study Results

Most athletes also reported interest in receiving study-level results from both any human performance studies they directly participate in as well as through the biobank. In addition to

providing the journal articles, the Alliance should consider including a simplified summary of the study's results, highlighting how this information may be useful to athletes either now or in the future. The Alliance should also consider incentives such as early-access to study results to enhance perceived benefits of biobank participation. Such actions would likely improve the general acceptability of the secondary research and may improve the health literacy of the participants.

The Alliance should also standardize language about when and how participants may receive individual results, if and how individual results will be shared publicly, and what resources and protections exist for participants. These standardized policies and procedures should be included in study consents and be made available on all public-facing platforms. Studies that do not provide direct benefit, including the biobank, should consider post-consent knowledge checks to ensure participants understand that they will not be receiving any information about themselves or any known direct benefits.

Commercialization

Background: Commercialization

Research participants views about the sale or sharing of research data and samples to commercial entities show this practice to be less acceptable and notification should be included in consents.[19,21,22,46,48,53,108,322-324] Issues related to commercialization of research, intellectual property rights across countries, and researcher partnerships with commercial entities have been described and discouraged in the Sports Genomics research community.[2,7,99] Conflicts of interest and commercial desires to bring findings to market before thorough validation are among the leading issues identified.[2,7]

Furthermore, name, image, and likeness (NIL) rights may make the commercialization of research using athletes' data problematic if any data is determined to be identifiable (see Section 4 for additional discussion about identifiability).[260,261] The boundaries for "Likeness" have been described as extending to any 'identifiable' information that describes an athlete's unique characteristic(s).[261] Despite rulings such as *Moore vs Regents of California*'s on the ownership rights of biological specimens and their derivatives, issues related to the concept of sample and data ownership remain unclear.[137,325] Furthermore, specimen and data abuses and misuses, such as the HeLa cells and Havasupai vs Arizona State, have been a source of mistrust for many communities.[137,326,327] The interest in profit-sharing and rethinking how commercial products may be incentives for research participation is growing.[56]

The literature is sparse regarding athletes' opinions related to the use of commercial products related to performance. Some of the ethical issues about team-directed and direct-to-consumer genetic testing for athletes have been explored in the global literature, with few US participants.[3,114,328-330] In general, athletes reported personal interest in tests that could improve performance and reduce injury risks, but the acceptability of team access to these results were variable.[3,18,116,117] Additional research into the ethical, legal, and social implications of these commercial products in the context of US sports is needed to understand the ramifications of such products across the life course of athletes.

Recommendations: Commercialization

As commercialization and sharing with for-profit entities are known to be less acceptable uses of research data and samples, the Alliance may consider either banning such endeavors or integrating these activities into the sustainment of HPR.[19,21,22,46,48,53,108,322-324] The Alliance should create and publicize a policy related to future commercialization and have legal

agreements in place outlining the terms and conditions associated with any future commercialization or sale of research data or samples to for-profit entities. Researchers and commercial entities who wish to profit from the research funded by the Alliance, including via secondary use of data and/or biological samples, should consider risks for future claims of ownership rights and/or profit-sharing. Considerations for contracts related to commercial use should include legal assessments of athletes' rights under the NIL regulations along with various state and international laws regarding ownership and identifiability (see Section 4 for discussions regarding identifiable data). Any decisions related to sample and data ownership and/or participants' rights, or lack thereof, to future profits should be explicitly included in all consent forms, data and sample sharing contracts, and should be publicly disclosed on all websites.

Furthermore, the Alliance is in a position to lead Precision Health research in building equity into the commercialization of research discoveries. Ways that equity could be embedded into the process include requiring a portion of profits to be returned to participants, be recycled into sustaining community-relevant research, and/or be used to lower costs of commercial products for participants and/or those who may lack access due to costs. One way to help return benefit to this community would be to have a mechanism in place that any commercialization would require a percentage of profits be used to fund healthcare and/or future research for retired athletes as this was a recurrent theme in athlete disparities (see Section 3 for additional discussion).

In addition to product development, the Alliance should create a policy that outlines the ethical boundaries of genetic modification using samples and data from this research. Gene-doping is perceived as an inevitable evolution in performance enhancement technologies, and the Alliance should be prepared to address any limitations in uses of biological materials and data

for enhancement purposes. Similarly, research discoveries from the Alliance have the potential to become commercial products, and it is anticipated that many products would be too expensive for lay people and aspiring athletes to afford. Therefore, the Alliance is encouraged to address the potential health disparities that commercialization of its research may result in and create policies addressing how products should be developed and delivered with equity and justice as the guiding principles. Finally, the Alliance should develop ethical standards to determine when innovations are therapies versus enhancements in collaboration with regulatory bodies to ensure that research participation does not negatively impact athletes' ability to compete.

Consent

Background: Consent

Broad consent for future, unspecified research (or secondary research) using "de-identified" samples and data has a long history of controversy.[19,137] Despite critics arguing that broad consent is not informed consent, the Office for Human Research Protections (OHRP) expanded and enshrined broad consent as a best-practice for secondary research as part of the Revised Common Rule.[137,151] Many research participants have expressed their desire to have more control over how their samples and data are being used.[19,137] Innovation in the consent form and process can also help promote research in diverse communities as participant engagement can lead to more culturally appropriate consent processes.[137,331,332] Furthermore, a recent federal ruling in Michigan has called into question the validity of broad consent for secondary research, and in Europe, the General Data Protection Regulation (GDPR) requires consent be obtained for each use of personal information.[111,229,333] Dynamic consent is one solution that allows participants to consent for each use of their samples and data, and it facilitates the return of study results to participants.[249,334] Implementing dynamic consent requirements investment and

infrastructure early in the biobank's creation and iterative participant interactions, but it minimizes the need to track differences in the original consents, such as restrictions on how samples and data can be used in the future.[137,335] Some researchers are turning to blockchain to manage dynamic consent as blockchain allows participants full control over how their samples and data are used and allows withdrawal from specific studies.[105] However, this technology maintains a permanent log, and it is still unclear if this permanent record would impede a participant's ability to fully withdraw from the biobank and/or the primary research study.[105]

Recommendations: Consent

An overarching theme in the interviews was the need to empower athletes as partners by being transparent, empowering athletes to make informed decisions, and providing athletes with more autonomy in research use decisions.

Transparency

Empowering athletes starts with ensuring that they are provided with all information necessary to make an informed decision about research participation. Although informed consent is standard practice for research participation, additional measures to promote transparency should be taken for recruitment of aspiring and professional athletes. The Alliance should consider creating template consent and protocol language to be used across sites to ensure messaging is consistent and minimize the variations across sites. This standardized consent should include information pertaining to Alliance policies related to confidentiality-related protections, data and sample sharing restrictions, commercialization, protections for and usages of sensitive data, return of results, medically actionable scenarios, and other policies and best practices employed by the group. The Alliance should also consider using one master research study that encompasses all moonshots and Innovation Hub projects to not only improve sample

and data access to studies that do not provide direct benefits to participants (see Research Effectiveness Section and Return of Results Section for additional discussion) but also to ensure that consents and research practices are uniform across sites. Standardized consent language will facilitate biobank operations by removing the need to review each original Alliance study's protocol and/or consent prior to authorizing sample and data sharing.

Consents should provide caveats related to risks for participation that relate to their professional career, such as potential for data to be identifiable and the subsequent potential for employment discrimination (see Confidentiality and Discrimination Section for additional details). Alliance policies regarding sharing data with potential employers, teams, commercial entities and/or sponsors, and other groups who have authority over athletes' abilities to compete should be explicitly included in consents. For example, study consents should disclosure of what, if any, authority figures will have access to samples, data, and/or individual-level research results. Consents should also explicitly state that there is potential for confidentiality and how this information may be used against athletes in contract negotiations, scholarships, play time, and/or endorsements.

Other athlete-specific risks should also be included in the Alliance's best practices. One risk that is particularly unique to athletes is that participating in scientific research may benefit their competitors in the future. This risk should be particularly emphasized if the study will not provide any direct benefits to the athlete. Any risk mitigation strategies, such as data-sharing embargoes, should also be discussed. Any studies that include invasive sampling beyond blood draws should clearly state what the potential performance-related risks are, both short- and long-term. As discussed in Confidentiality and Discrimination Section, small subgroups and outliers have much higher risks for confidentiality using traditional 'de-identification' methods, and risks

related to re-identification extend to any public sharing of results or data that is not aggregated or masked. Studies seeking to enroll potentially vulnerable subgroups should include extra verbiage that specifically addresses this risk and any added protections along with their limitations to ensure athletes are truly informed. As discussed in Commercialization Section, any potential for future commercial profits, including sharing samples and data with for-profit entities, should be clearly stated along with what, if any, ownership rights participants have with regards to their samples, data, or profits derived from their samples and/or data. If commercial profits will be returned for either personal or community benefit, this information should also be included in the consents.

Clear explanations for why various samples, datasets, and sensitive information (such as genetic or mental health data) are both necessary to their research and how they may be used to improve health should be included in all consents. Any restrictions on sharing and/or enhanced protections related to sensitive information should be included as well as any limitations to these efforts. Similarly, any policies restricting potentially controversial research activities should be made available to participants and if relevant included in the consent. For example, if the study seeks to extract DNA, the consent should include clear explanations for how it will be used, stored, and any restrictions to how it may be used via secondary research through the biobank. If studies do not consent for DNA usage, then the consent should explicitly state that such data will not be extracted without additional consent. Studies that include video or motion imaging should address how data will be anonymized, limitations to anonymizing efforts, how data will be securely stored, and what other types of information, particularly sensitive data, may be shared with this potentially identifying imaging data. As discussed in the Return of Results Section, therapeutic misconception about research participation is very prevalent across all types of

research, including biobanks. Therefore, it is also important that all efforts be made to clarify what, if any, information will be returned to the athletes and whether they may anticipate any personal benefit.

Enhanced Consent

The Alliance should create policies and best practices for research that may be controversial. For example, should the Alliance determine there may be times when it would be appropriate to share information with employers or other authority figures, this should be considered a sensitive use-case and explicit individual consent should be required for this data-sharing. Explicit consent could be incorporated into the original consent by asking a participant to initial that they understand data may be shared with organizations that employ athletes. Similarly, the Alliance should consider requesting explicit consent for use of sensitive data, including samples as they contain DNA, or data that carries a high risk for re-identification. The biobank should also consider obtaining individual study consents for future research uses that require sensitive or potentially identifiable data. Furthermore, individual consent should be considered for any research studies for which Institutional Review Boards and/or Alliance researchers feel the study is potentially greater than minimal risk. Similarly, the Alliance should consider requesting explicit consent and/or individual study consent when samples and/or data will be shared with for-profit organizations or for commercialization efforts. At a minimum, it is recommended that the Alliance notify participants of these uses and reiterate any limitations to participants' rights to profits to improve transparency and potentially prevent future legal disputes.

When studies are unable to ensure that participant's identity will be protected, athletes should be provided with the option to restrict sharing of their information to aggregated data

sharing only or sign an acknowledgement that they understand the risk and are willing to allow potentially identifiable information to be shared for future research purposes, public presentations, publications, and other relevant activities. Other forms of requesting research participants' preferences at the time of initial consent could be considered. For example, participants may be offered the opportunity to restrict or allow data sharing of sensitive information, access to authority figures, and/or use for commercial purposes. Problems with capturing preferences at the time of enrollment are similar to the problems with broad consent as future research cannot be anticipated and new use cases may arise that fall outside of predetermined categories.

Empowering athletes through consent could be optimized by allowing participants to control how their samples and data are used for future research. Dynamic consent would allow participants to consent, either opt-in or opt-out, at the study level for all secondary research studies. Requiring opt-in consent for each would align with GDPR (European) requirements and allow for the return of individual research results (as well as study results; see Return of Results Section), but opt-in consent has been said to be cumbersome over time.[19] Providing participants with the opportunity to opt-out of secondary research at the study level allows for the current process of defaulting to sample and data sharing while still providing athletes with the ability to control how their information is used. Similarly, this process would improve transparency about what research the biobank is facilitating. An opt-out process would still allow for the return of study-level results (see Return of Results Section).

Therefore, the Alliance should create a policy and best practice for researchers to address future consent and standardize this throughout all studies. The Alliance should determine whether study-level, enhanced consent methods are appropriate and for what circumstances. The

Alliance should weigh the anticipated benefits of improving recruitment by incorporating more transparency and control against the potential decreased availability of samples and data for some research studies. Decisions regarding enhanced consents should be driven by athlete engagement (see Engagement Section). For example, dynamic consent could be either an active signing or opt-in process or an opt-out process or allow participants to choose and change between opt-in and opt-out via a biobank-participant user portal. Although this process will require front-end infrastructure, incorporating study-level consent for all secondary research is expected to improve recruitment and retention both by empowering athletes, adding transparency, and facilitating the return of individual- and/or study-level results. However, for enhanced consent to be an effective method of improving transparency and empowering athletes, it must be designed and implemented in a manner that is acceptable to athletes.

In addition to dynamic consent, many participants suggested that athletes be provided with a "menu" of options related to what types of biological samples were being requested and why each type of sample would be scientifically important. Although these suggestions may improve recruitment, invasive sample collections were generally unpopular with athletes as they feared the procedure would impact their training and/or performance. The Alliance should determine what, if any, biological samples are necessary from participants and provide clear explanations for why these samples are important. Similar explanations for optional samples would benefit the consent experience. Furthermore, regular engagement with participants to maximize the researchers' ability to scavenge clinical samples may improve sample collection. Again, transparency is critical even when collecting left-over samples.

Consent Process

It is also important for the Alliance to establish best practices for how consent is obtained and by whom. Many participants indicated that recruitment through teams and affiliated support services, such as specialists, would likely increase access to athletes, both in college and professional settings. On the other hand, high revenue-generating sports at the professional level universally reported that if the Alliance involved teams or leagues in recruitment that it would cause athletes to distrust the motivations of the research. People in positions of power were reported to be not ideal candidates for requesting research consent as perceived conflicts of interest may make the voluntary nature of participation questionable. Whenever possible, a third-party member of the research team should obtain consent. When a neutral third party is unavailable, researchers who are also engaged in training and supporting athletes in a professional capacity should be trained in informed consent best practices.[137,336,337]

Researchers should also strive to incorporate trusted advisors, such as players' associations, agents, and family, into the consent process, especially when sensitive data will be collected. Therefore, to improve the sustainability of this research, clear communication about expectations for when, what, and any limitations to the information and results they will have access to will be invaluable to maintaining athletes' and non-athlete stakeholders' buy-in to this research.

Engagement

Background: Engagement

The lack of diversity in Precision Medicine research has led to many researchers turning towards actively engaging in communities and participants to build trust and research capacity. [137,218] Due to the ethical and logistical complexities involved in Precision Health research, robust community engagement and shared decision-making is essential for recruiting and sustaining

complex and on-going Precision Health research.[54,60,137,155,218,308] Many biobanks and learning health systems have also utilized engagement to inform their governance structure, and most participants voiced concerns about potential harms with data sharing and emphasized strict regulations on for-profit companies' access, diverse representation, and need for enhanced, culturally appropriate communication and education of ethical issues to participants.[53,69,77,106,112]

There are numerous ways to include participants and other stakeholders in research design and governance, ranging from community-based participatory research to advisory boards. However, implementing community recommendations can be difficult as researchers need to balance research needs and oversight requirements against community input.[61] These conflicts of interest are to be expected, particularly for issues of values, control, privacy, transparency, and profit.[137] Questions about the public good and potential for harm of proposed research studies should be expected and offer researchers the opportunity to engage in discussion and incorporate the values of their participants into the governance of the research.[137] The amount of power is often defined by the organization, and a lack of empowerment can lead participants to feel tokenized.[63] The Veterans Health Administration, or VA, offers guidance for how power dynamics can be recognized in a Community Advisory Board (CAB), decision-making procedures to sustainably empower participants, and considerations for interventions to address balance-of-power issues.[63] Similarly, the Mid-South Clinical Data Research Network provides recommendations for how to meaningfully engage with a wide variety of stakeholders to ensure the research is participant-centered and -informed.[69] Another successful method reported is deliberative community engagement that incorporates education and discussion before voting on governance and oversight recommendations.[77]

Recommendations: Engagement

In addition to the need for the Alliance to promote honest, transparent, and appropriate individual-level decision-making via informed consent for research participation and sample and data usage (Consent Section), nearly all participants reported that not including athletes in the decision-making process would be problematic. Although not explicitly discussed in the interviews, engagement with athletes will be especially important as the donors funding these research initiatives are themselves owners of professional sports teams, and distrust amongst team-sport athletes was a pervasive theme. The Alliance's highlighting of the donors' names in the Alliance's name improves transparency regarding their positions, but it may be insufficient to overcome the deep mistrust of athletes towards team owners and leadership. Furthermore, it is reasonable to anticipate that any decision-making that is perceived by athletes as being 'top-down' will be all the more objectionable to athletes due to perceived conflicts of interest that those in positions of authority having ulterior motives, including researchers themselves. Therefore, engaging athletes in decisions about research policies, practices, and study acceptability is expected to be critical to successfully implementing a large-scale research initiative that includes aspiring and/or professional athletes.

It is also important to note that this engagement should be designed as a partnership, as opposed to advisory boards that have no power beyond offering opinions. This partnership mentality was reported as being necessary amongst team staff for collection of any new data or new research initiatives and aligns with national trends supporting the ideal of empowered athletes. In addition to considering giving individual participants control over how their samples and data are used via consent (Consent Section), the Alliance is encouraged to engage with a Community Advisory Board (CAB) that comprises a wide variety of athletes with diverse

backgrounds along with trusted advisors identified by the athletes. The Alliance should consider implementing a deliberative democracy method that encourages two-way education and group discussions prior to making decisions. Furthermore, the Alliance should set out transparent policies that identify how power will be shared with the CAB, including a process for when conflicts arise.

Other key stakeholders were identified as also being necessary to create successful partnerships with athletes: players' associations, athlete-trusted medical and training staff, and more peripherally, agents and training staff. However, players' associations were generally seen to be the most important group who can advocate for athletes' rights and needs, particularly representatives from high-grossing professional team-sports. Any engagement with teams, leagues, or sponsors should be done in partnership with players' association representatives to promote trust and transparency. As not all sports have strong players' associations, it is recommended that representation of players' associations from the highest grossing sports be extended to address protections for all athletes. Similarly, the Alliance may need to take proactive measures to ensure historically underrepresented subgroups, such as female athletes, are equally or even over-represented (see Disparities Section for additional recommendations). By including strong players' associations, the Alliance will be demonstrating that players' health and well-being are the driving factors of the research. Players' associations may also be critical partners to aid with recruitment, data collection, and navigating partnerships with athletes and other parties. Furthermore, most athletes agreed that protections for the most extreme risks would benefit all athletes.

With regards to including medical and training staff, by and large it would not be appropriate for medical staff to be affiliated with a team as team physicians were generally not

trusted. Similarly, it was recommended that medical and scientific advice not be restricted to coming from the Alliance researchers and associated physicians, so it would be important for non-Alliance affiliated researchers to be invited into decision-making discussions. Training staff and agents will be key stakeholders to engage with as they are generally well-trusted and regularly discussed as being important educational conduits. Engagement with team training staff for research recruitment would not be inappropriate at this time, but private trainers were perceived to be less likely to have a conflict of interests and may be an alternative resource. Overall, decision-making and advisors of athletes should be free of any possible conflicts of interest and identified by athletes as being trusted individuals.

Athletes should also play a major role in driving communication plans as athletes are reported to be quick to spread information amongst each other when they suspect disingenuous relationships or feel they are being exploited. Missteps by the Alliance in public communications could quickly jeopardize both recruitment efforts and long-term sustainability of the research mission. Nearly all athletes reported that receiving study- and individual-level results was necessary for research participation (Return of Results Section), but the perceived benefits of this information will require the findings to be presented in a meaningful way. Finally, in addition to wanting to be part of the decision-making process for how samples and data are used, it will be vital to include athletes in the development of study summaries to ensure that the communications are both intelligible and meaningful. Therefore, athletes should be engaged in discussions about what and how information related to research studies should be disseminated to participants.

Beyond the power and composition of a CAB, communication will need to be athlete/participant centered. It was also emphasized in Athlete Characteristics, Research

Effectiveness, Disparities, and Return of Results Sections that the research itself needs to be focused on the participants and meaningful to the community. It was frequently pointed out that research for the sake of research would be insufficient for elite athletes to sacrifice their time, energy, and control over their samples and data (Athlete Characteristics Section and Research Effectiveness Section). Therefore, it is important that athletes be included in the scientific review process for in-person research studies to ensure that athlete buy-in is obtained, the research is meaningful to the community it seeks to serve, and to provide feedback regarding study design, processes, and practices. Similarly, as discussed in Confidentiality and Discrimination Section, the Alliance should collaborate with athletes and other stakeholders to develop a policy and best practices to maintain confidentiality when storing and sharing potentially re-identifiable information, including samples, publicly or with any authority figures in sports: regulatory bodies, employers, teams, universities, and sponsors. Although some of these issues may be able to be addressed with enhanced consent methods (Consent Section), athlete partnerships will be crucial throughout the research process, including developing the consent verbiage and processes.

Athlete engagement was a central theme in all sections of this study's findings. Successful engagement will include athletes in a meaningful way, empowering them to be involved in decision-making and policy development. Athletes are vital resources for helping researchers design, recruit, and relay study information to ensure that the research is meaningful for both parties. Although athletes often have a number of people in supportive roles, there are high levels of mistrust in professional sports. Athletes trust each other and a limited number of other stakeholders, so in addition to working with the athletes, the Alliance will need to support

athletes in identifying and working with other non-athlete stakeholders throughout the research implementation process.

White Paper Conclusions

All participants indicated that the proposed HPR was meaningful and generally acceptable, although some questioned the research's ability to deliver utility and benefits to both the general public and participants. Furthermore, studying extreme states of health raised new ethical concerns, and aspiring or professional athletes were determined to be at higher risk for re-identification and discrimination if research data and results were to be shared with or accessed by employers. Suggestions for addressing risks of re-identification are primarily rooted in the Alliance's data and sample collection, storage, and sharing policies. Collecting only the information necessary to address hypothesis-driven research questions was one way of protecting the participants, but it would likely severely impact the ability of researchers to explore other aspects of elite performance. Data perturbation would make re-identification much harder, but it too carries the risk of confounding future research and would require thoughtful and informed implementation. All studies, particularly the biobank, should obtain a Certificate of Confidentiality from the NIH to prevent researchers from being forced to release study data or samples. Another relatively easy way to protect athletes from discrimination would be to place embargoes on data and sample sharing until athletes retire. Embargoes would also address concerns that participating in research would provide up-and-coming athletes with a competitive advantage over the participants.

All participants also reported understanding the utility of a biobank for researchers, with some appreciating its potential to facilitate HPR. Scavenging clinical samples and medical record information was generally perceived as the most acceptable way to recruit directly into the

biobank provided detailed consent was provided. Many athletes were also amenable to contributing to a biobank through participation in a study that returned direct benefits to themselves. However, most athletes and participants advocated for giving athletes more choice in what data and samples are collected and how data and samples are used in the future. Participants also responded positively about partnering with UNESCO to ensure the samples and data would be available worldwide. Although some noted potential access issues for researchers in under-resourced areas and ethical issues related to allowing access to countries with poor human rights protections.

Overall, research participation was discussed as a transaction where athletes provided their time, effort, samples, and data in exchange for useful information related to their own performance. Altruism was a notable reason for participating in research, but it was tempered by risks of discrimination and lack of personal utility. Therefore, in order to recruit athletes at the peak of their performance, the Alliance will need to find innovative ways to return benefits to participants. One way would be to recruit athletes into a master study that encompasses all moonshots and innovation hub initiatives. This method would maximize the opportunity for athletes to receive meaningful feedback while also providing more access to bench and exploratory researchers who are less likely to provide useful study results in a timely manner. In addition to providing individual results, access to resources, early access to study results, and profit sharing were identified as other ways the research could return meaningful benefits to participants.

This study also identified the potential for the research to either exacerbate or create new health disparities amongst athletes and researchers. Moral issues related to eugenics were raised along with concerns about the ability of research with elite performers to be generalizable to the

public. Generalizability within athletes is also a major concern as historically many communities have either been exploited or outright excluded from research. This study also was unable to recruit a diverse sample of athletes, which is a major limitation of this study. The best course of action for the Alliance is to require researchers to recruit a representative sample and engage a diverse group of athletes to partner with to inform how the research is designed and conducted.

Empowering athletes in decision-making was a major theme in this study's interviews. Athletes frequently expressed the desire to control both how their samples and data are used and shared as well as inform who has access to any individual results. In addition to allowing individuals to consent for secondary research studies, the Alliance is strongly encouraged to partner with athletes in developing policies and research processes. Allowing athletes to partner with the Alliance is anticipated to improve recruitment and retention. Additionally, this partnership is expected to improve the generalizability of the research by aiding researchers in connecting with more diverse participants. Similarly, this partnership is expected to lead to more perceived value as athletes can advise on what results would be most meaningful and how best to deliver information to the athletic community.

Empowering athletes also requires engaging their trusted advisors. These advisors include players' associations, agents, training staff, private support staff, and family members. Athletes reported that they would be more comfortable engaging with researchers if they had independent medical staff to help explain the research and to verify meaningfulness of the prospective research. This feedback should be considered when developing best practices for recruitment at the individual level as well as informing who should be included in the CAB.

The Alliance is uniquely suited to address issues that are particularly relevant to professional athletes and aspiring professional athletes due to its wide scope and multisite

consortia. By leveraging these advantages and designing the research to meet the needs of the most extreme use-case, professional athletes, these changes are anticipated to confer benefits to other cohorts. For example, military personnel may fear employment discrimination related to military access to individual-level data, but Alliance policies that include protections against employers accessing individual-level data will address discrimination across all cohorts.

Similarly, the Alliance is unified to further multiple moonshots. By standardizing research enrollment, policies, consents, protocols, and procedures, the Alliance could either enroll all participants into one larger study or ensure that all Alliance-funded research is conducted using the standardized best practices. Centralizing enrollment would maximize the chance that individual participants may have access to meaningful results and/or direct benefit. For example, a participant in the digital twin study may be able to gain insights into their movements to improve their performance and/or decrease their risk of injury. Whereas a participant who donates muscle tissue for epigenetic studies may only have the anticipated benefit of contributing to generalizable scientific discovery. Simultaneously, this centralization will improve access to samples and data across sites for studies that may not produce individual-level results in a timely manner, if at all. Unifying study recruitment would also allow for consent standardization and easier enforcement of Alliance policies related to security and governance of samples and data by biobank staff. As many athletes indicated an interest in choosing what types of data and sample they shared, this larger study could offer participants the option of choosing what research aligned with their comfort and interests. For example, participants could be offered a menu of types of biological samples they can donate and choices over how those samples could be used. Such standardized consent would drastically reduce the burden of the biobank to know what each disparate study allowed, such as DNA extraction. By

including or offering enrollment into all moonshots and Innovation Hub studies, the Alliance can also ensure that Alliance-wide resources are equally available to all participants, again increasing the potential benefit to participants.

Standardizing Alliance policies and procedures to focus on equity can also help mitigate risks for widening health disparities beyond generalizability of Alliance-funded research. For example, the Alliance has promoted partnering with UNESCO to ensure that samples and data are available to researchers worldwide. However, under-resourced researchers, such as those from low- and middle-income countries (LMIC), may not have data storage capabilities or access to sequencing technologies. By planning for equitable access, the Alliance can consider building secure, cloud-based storage that includes analytic tools to allow all researchers to run inquiries using standard internet connections. The Alliance should also consider sequencing all samples in-house and storing omics data centrally. This would minimize the risk that unauthorized sequencing and allow stricter regulation on how sensitive information is viewed and used. The more control the Alliance's biobank has over samples and data also facilitates options for providing dynamic consent for secondary research and returning study-level research results. This data and analysis centralization will also improve security and confidentiality concerns as this minimizes or removes the need to allow external researchers to download individual-level data or share samples and data with unauthorized third parties. Maintaining control over the data in this way also removes the concern that datasets will be shared outside of the oversight of the Alliance or used for unauthorized purposes.

Addressing issues of confidentiality, data protection and access, transparent communication, and empowering athletes to be decision-makers will be critical for short- and long-term success. Additional legal reviews are recommended regarding athletes' rights and

ownership disputes as well as an evaluation regarding the applicability of federal, state, and international protections related to research information. Additional research is recommended to understand the unique needs of the other various cohorts, such as military or children, being sought to participate in the Alliance's research. As such, it is recommended that stakeholders from other cohorts be engaged to identify unique characteristics, contexts, and concerns prior to enrollment. Furthermore, these other elite performers should be engaged as partners as well in a CAB to help guide policies, research design, and inform best practices.

4.2 Limitations

Methodological Limitations

Although the choice of recruiting key informants facilitated the feasibility of this study, it has its own limitations. For example, this sample is not intended to be representative of the general target population, particularly those with less education or who identify with marginalized communities. By seeking a wide variety of stakeholders, we sought to understand the landscape in which this research intends to operate, identify barriers to conducting HPR and biobanking research, and understand what potential conflicts of interest may exist within this complex system of stakeholders who are influential in the decision-making process of professional athletes. As such, the results of this study will not be able to summarize professional athletes' views in general, but it reports the views of those who participated. Furthermore, this study sought to understand the potential risks and benefits associated with aspiring and professional athletes' participation in HPR and/or biobanking, so the purposive sampling targeting medical and legal experts is expected to provide more factual data compared to the more speculative health benefits and legal risks proposed by non-expert participants. It is important to note, however, that qualitative methods more generally are not intended to

generalize findings and rather are intended to be hypothesis generating. It is also important to note that many of the athletes enrolled in this study were retired, so the willingness of actively competing athletes to both engage with researchers and participate in research studies may not be reflective of athletes who would not self-select for this type of research study. Additional research is recommended to further explore the perspectives of athletes who are less well educated, are from racial or ethnic groups that are underrepresented in this study or from underserved and/or marginalized groups as their lived experiences are expected to have led to different expectations and concerns related to research participation. This future research should partner with trusted stakeholders, such as Players' Associations, and offer provide opportunities for athletes to engage with researchers in a wide variety of formats that require minimal time and energy from the athletes (e.g., short surveys or meeting athletes at their training facility for short discussions).

Similarly, all three recruitment methods employed (purposive, snow-balling, and convenience sampling), while well-accepted in the field of qualitative research, increased the risk of sampling bias due to the fact that individuals nominated and recruited from the target population did not all have the same chance to participate. Similarly, convenience and snowball sampling risk recruiting like-minded participants resulting in an artificially homogenous sample. To mitigate this risk, the study requested connections to specific individuals whenever possible, and requested that participants recommend people who have different backgrounds, lived experiences, and opinions from themselves. Nonetheless, these recruitment strategies resulted in a sample that was not representative of the racial and ethnic makeup of the athletic communities it engaged with. This is an important limitation as many of the voices missing from this study are from historically underrepresented and marginalized communities and likely include different

themes and experiences than those from majority races and ethnicities. As the lead researcher was not an "insider" to the professional sports community, this study relied on the existing connections within the Alliance at-large. The research team hopes that the lack of diversity in this qualitative study serves as a beacon to call on the Alliance teams to be proactive in ensuring that their research studies are representative samples of the global community which they seek to serve.

In addition, it is important to note that it is always possible for the researcher to introduce bias into the interview process. To prevent this as much as possible, the researcher was trained in qualitative methods and had conducted qualitative research prior to this study. Furthermore, a qualitative research expert periodically reviewed transcripts to identify opportunities to minimize bias and redress problems early. Of note, the primary researcher (JC) has professional experience in the ELSI of genomics research. This researcher's personal opinions include the beliefs that health data cannot truly be "de-identified" and that broad consent is not a valid form of informed consent. To mitigate these biases, the researcher would ask probing questions when participants used terms or phrases such as 'anonymous' or 'I would want to know how my samples and/or data were being used.' These probing questions sought to prompt the participant into sharing more about their understanding and expectations related to confidentiality and decision-making to avoid applying the researcher's personal perceptions to vague statements. It is also well-established that the researcher in a qualitative study is a key instrument in data collection and analysis and that, with proper methods to minimize the impact of the researcher's own bias, the researcher's past experiences and reflexivity with respect to the participants and data are strengths that allow for a more holistic collection and interpretation of the data.[34] In the case of this study, the researcher also has field experience with the establishment and maintenance of

multiomics research biobanks and is able to facilitate clarification and further contextualization when needed during the interview process.

Another way that this study sought to minimize bias during the interview process was to use an interview guide that was vetted by multiple researchers for clarity and accuracy. Furthermore, this study conducted four pilot interviews with college athletes in order to identify any points of confusion or questions that were limiting responses. Following these pilot interviews, this study sought to follow the interview guide as closely as possible and consistently for all participants. However, as these were semi-structured interviews, the interviews remained flexible to explore related topics and points that interviewees identified from the predefined questions. As a result, this study resulted in a robust discussion with a wide variety of stakeholders, and provided a large breadth and depth of insight into the contextual factors in the professional sports environment that may impact the level of successful implementation of HPR and biobanking.

4.3 Future Research

This study demonstrated how DIS and engagement can be conducted during the exploratory and design phases of Precision Health research. This study also demonstrated how incorporating the rigorous methods and measurement tools from DIS, researchers can optimize engagement strategies, identify what adaptations are appropriate for different contexts, and evaluate the return on investment of these strategies and adaptations in future implementation phases of the research process. One method commonly used in DIS research is to conduct a thematic analysis of team meetings, communications, and study discussions (both formal and informal).[338] By incorporating this data collection into the implementation strategies, researchers can obtain additional qualitative data that can provide insights into the contextual factors

impacting an iterative implementation process.[338] Regular thematic analysis can help identify contextual barriers and facilitators to implementation. Future research throughout the HPR and biobank implementation should include continued qualitative data collection, consider employment of quantitative measures for acceptability, appropriateness, and feasibility, and collect data on effort and costs associated with both engagement activities and adaptations.[23,28,129,131,132,136] During the design phase, this study's findings and recommendations will guide data-informed decisions that ideally the researchers will make in partnership with their community advisors. This decision-making process will require researchers to determine what implementation outcomes will be prioritized and what feasibility limits are acceptable, such as the amount of funding that is acceptable for improving the implementation outcome of interest. Costs and outcome impacts will be estimated during the design phase that can later be measured during the implementation phase. Connecting the contextual factors and implementation strategies (including adaptations to practices) to implementation outcomes will be vital to building empirical evidence to support equitable and representative Precision Health research intervention implementation moving forward.[339]

There were a number of relationships identified between contextual factors and implementation outcomes, and future research should test these relationships. Some recommendations would be to continue engagement efforts with athletes and quantitatively explore how much any Implementation Strategy or recommendation identified herein changes their opinions about the acceptability of the research and their willingness to participate in the research. On-going qualitative work should also be considered as various stakeholders may identify new logistical or ELSI concerns related to the research itself or to one of the adaptations made in response to athletes' initial feedback. Another recommendation is to assess how any

changes made to the research design, policies, and/or practices impacts both the research and the stakeholders in a more pragmatic evaluation. For example, does an opt-out, study-level consent decrease secondary research participation rates significantly or negatively impact the participant's experience? Questions such as these remain unanswered in the literature, but there is evidence that providing participants with greater control over their samples and data through one of the many types of dynamic consent does correlate with higher research participation and retention rates.[102]

Due to the complexity of both HPR and biobanking, it will be necessary to assess these contextual factors and make adaptations to the intervention (a HPR biobank) by iteratively engaging a variety of stakeholders within each cohort throughout the planning, design, and implementation process. This initial and future on-going, iterative engagement will provide data that can inform the adaptation process. By engaging the community, the Alliance will increase the likelihood that the proposed HPR biobanking intervention is acceptable to professional athletes, appropriate for the related organizations (such as players associations), and feasible and cost-effective for researchers (Fig. 2.1). These implementation outcomes are theorized to improve the *Reach* of the study to enroll the target population, the *Effectiveness* of the research to promote human performance inquiry, the *Adoption* of this research across various stakeholder organizations, and the *Implementation* of this research in a manner that is still in-line with the needs of the researchers themselves (Fig. 2.1).[32] Finally, successful implementation should also result in successful *Maintenance* of these research activities throughout the course of the Wu Tsai Human Performance Research Alliance's work (Fig. 2.1).[32]

Future research aimed at solving some of the outstanding issues is also highly recommended. For example, researchers should consider if and how artificial intelligence (AI)

and/or machine learning could be employed to facilitate adaptations that minimize risks. One consideration would be to determine if these technologies could be used to iteratively generate hypothesis-driven data perturbation, thus masking data not anticipated to impact the research question in order to decrease risks of re-identification, similar to the more static differential privacy techniques currently employed.[340] Due to the complexities of exploratory research with multiomics methods, it is presumed that AI would be better suited to identify potential correlations that may be relevant than a manual, human generated masking effort. Another application to consider is whether generative text AI could be used to translate scientific requests into plain language for dynamic consent purposes and/or return of research results, both study- and individual-level.

Although beyond the scope of this proposal, it is also expected that the results of this study could inform the development of a survey that can gather more generalizable data about the knowledge, attitudes, and beliefs of professional athletes. Similarly, the results of this study will also aid in the administration of such a survey as this study was intended to help researchers understand how best to interact with professional athletes and their stakeholders; for example, it was suggested that partnering with Players' Associations could facilitate large-scale data collection. As previously discussed in Aim 1, this study provides researchers with key topics that need to be discussed prior to recruitment and will allow for more in-depth qualitative data collection during these future engagement activities that will provide much more depth from analyzing these discussions. The results of these interviews can also help inform the design of measures to iteratively assess implementation outcomes, such as measuring acceptability of the intervention with respect to key thematic concerns. These unique measures can then evaluate the process and outcomes of the implementation of a HPR biobank.[32,189] Finally, this study also

provided and adapted structured coding in accordance with the PRISM to facilitate comparisons between the cohorts and guide empirical data collection throughout the implementation process that would allow tracking and assessment of both the sources of adaptations and impact of adaptations to the HPR biobanking designs and policies have on the various implementation outcomes.[28,31,32,136] Such empirical data may be able to guide and inform other biobanks on what adaptations and contextual factors to consider for their populations.

4.4 Conclusion

As previously discussed in the justification for why DIS is necessary to be applied to research intentions, Precision Health researchers have the opportunity and arguably the moral imperative to improve diverse representation in research and thus decrease health disparities in the field. This mandate is particularly true for the researchers with the Wu Tsai Human Performance Alliance as they explicitly intend for their research of elite performers to translate into benefits for the general public.[5] Furthermore, the potential global impact of this research on musculoskeletal injuries could improve quality of life for millions of people not to mention the billions of dollars in economic impact that could be saved.[38,39] For this bench and intervention research able to be implemented at the population level, it is imperative that these researchers engage with potential and current research participants and related community stakeholders to adapt their research designs and practices to be more inclusive and more acceptable to the most vulnerable.[59,132]

As previously hypothesized and reinforced by the interviews, professional athletes are most likely the most vulnerable population due to the higher value of their data and increased likelihood of re-identification and potential for discrimination. Equally important is that the risks at the professional level apply to athletes who are or may be aspiring to become professional

athletes. Therefore, researchers working with aspiring and/or professional athletes may need to take extreme and novel actions to minimize potential harms and maximize potential benefits related to research participation. Proactive policies and adaptations to traditional research practices, such as broad consent and "de-identification" methods, are necessary for the Alliance, and Precision Health more broadly, to equitably advance to the population-level. By incorporating DIS methods, this study highlights the logistical and ELSI that researchers will need to consider and balance in order to successfully implement HPR and biobanking into this population. Furthermore, this work provides the Alliance with data to guide them to where critical decision points are, such as confidentiality, providing participants with direct benefits, and sharing decision-making with the athletes. The data from this study combined with the various DIS outcomes can help researchers weigh the risks and benefits of various recommendations, determine their implementation goals (such as generalizability or traditional research efficacy), and determine the financial value that is appropriate to invest towards meeting their goals. During the implementation phase, the Alliance will have the tools to measure the return on investment gained from any adaptations made to their research study designs and practices. By measuring and reporting these logistical and ELSI iteratively from the exploratory phase through the sustainment phase of this research implementation process, the Alliance will be able to make informed decisions regarding other cohorts as well as build a body of data related to the changes most associated with making HPR and biobanking more acceptable and accessible to professional and aspiring athletes in the US.

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4.5 Tables and Figures

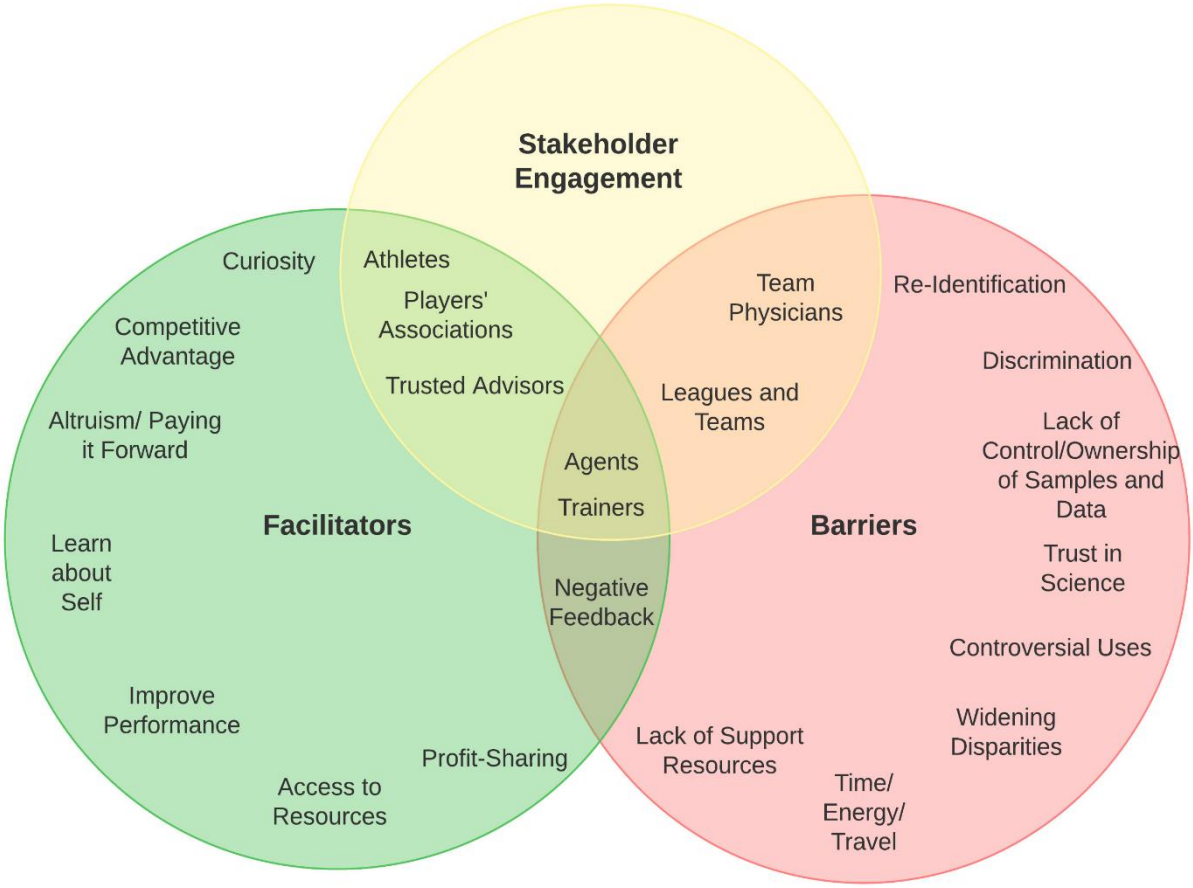

Figure 4.1: Key Barriers and Facilitators to Precision Health Research and Engagement:

This figure identifies many of the barriers and facilitators to Precision Health Research with professional athletes in the United States. It also identifies stakeholder groups that were generally recommended to be included or excluded from future engagement activities. It is important to note that these stakeholder groups were not described as universally positive or negative, but instead, this diagram represents the major trends in the participants' feedback.

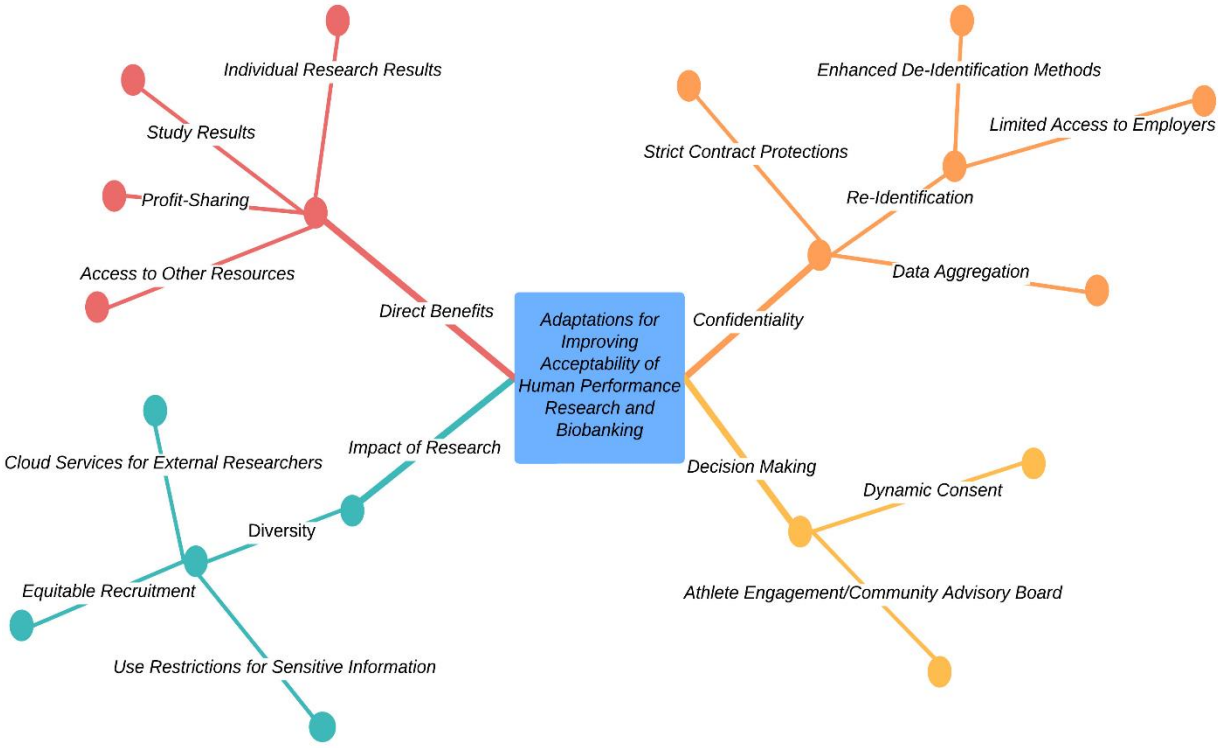

Figure 4.2: Major Themes Related to Human Performance Research and Biobanking and Potential Adaptations to Improve Acceptability:

This figure connects the four major themes of Confidentiality and Discrimination, Need for Direct Benefits, Impact of the Research, and Decision Making identified in the key informant interviews to the potential adaptations of policies, procedures, and study designs anticipated to improve the acceptability of human performance research and biobanking. These adaptations are included in the White Paper's Recommendations.

Table 4.1 Top Recommendations for Leadership

Top Recommendations for Alliance and Biobank Leadership
1. Utilize a wide variety of techniques to anonymize data, such as data perturbation, data aggregation, and data embargoes.
2. Create a policy to address restricting what kinds of data and results may be shared with teams, leagues, and regulatory bodies to minimize risk for discrimination for athletes.
3. Engage and empower athletes to inform research policies and practices.
4. Establish a policy that defines acceptable and unacceptable uses of samples and data, particularly sensitive data such as mental health or genetic information.
5. Establish policies that promote diverse recruitment and equitable return of benefits to participants.
6. Establish a policy regarding commercial use of and commercialization from Alliance-funded samples and data.
7. Obtain legal reviews to futureproof Alliance policies and practices.
8. Implement legal contracts that include restrictions on uses and penalties for violating approved uses and/or breaching confidentiality for external and internal researchers.
9. Continue to conduct ethics assessments for other cohorts, such as military personnel and child athletes.
10. Consider hosting data and analytic tools on secure Cloud platform to facilitate future research by low-resourced researchers.
11. Consider restructuring research to maximize benefits for participants and improve data and sample access for exploratory researchers unlikely to provide direct participant benefits.

Table 4.2 Top Recommendations for Researchers

Top Recommendations for Human Performance Researchers
1. Engage athletes to inform recruitment methods that capture diverse, representative samples (for the sport not only one site), potential benefits for research participation, and communication preferences for returning study results.
2. Consider dynamic consent that allows athletes more control over what samples and data are collected and how they are used in the future.
3. Avoid collaborations with authority figures, such as teams, without athletes and/or players' association guidance.
4. Emphasize confidentiality both internally and externally and determine what variables may be identifiable for athletes.
5. Incorporate 'grit' and mental health assessments into research studies.
6. Plan for possible medical and mental health interventions when collecting data that could reveal health concerns or crisis.
7. Utilize research ethics consultations for studies using genetic, mental health, and/or other sensitive information.

Table 4.3 Summary of Study Findings and Recommendations

Primary Findings	**Summary of Primary Findings** (Not a 1:1 association with Recommendations)	**Recommendations** (Listed in order of priority; Not a 1:1 association with Summary)
Vulnerabilities		
Athlete Characteristics	• Institutional and legal supports for athletes vary by skill, level, and type of sport • Regular physical assessments and public sharing of health information may desensitize athletes to the risks associated with research participation • Individual sports are more likely to be self-funded • Time is a universally limited resource for elite athletes • Altruism towards research participation is often balanced against the competitive nature of sports where research participation will likely be more helpful to up-and-coming competitors, particularly if no individual results are returned • May be prone to coercion if recruited by authority figure • Recruitment of children may not be appropriate	1) Apply of highest protections for all participants 2) Engage athletes in study design, policy, and recruitment decisions 3) Collaborate with multidisciplinary teams to plan for mental health and medical interventions 4) Consider enhanced incentives for cohorts of athletes with low individual resources and/or support, such as individual sports 5) Recruitment should be done using an unaffiliated research coordinator 6) Strong scientific justification and proactive support should be considered if recruiting children athletes
Confidentiality and Discrimination	• Elite Athletes have disproportionately more publicly available health information • Legalized sports gambling and celebrity status increase the value of athletes' health information • Some data, such as DNA and mental health, are considered more sensitive • Sharing video and/or phenotypic information may be identifiable in this population • Possible types of discrimination related to research data included play time, scholarships, contract negotiations, drafting positions, future insurability, and employment • In team sports, employment and insurance are based on physical performance making risk for discrimination related to research data and/or findings higher	1) Sample/data storage and sharing policies that expand definition of 'identifiable' data and samples beyond minimum requirement 2) Enhanced data security methods, particularly for more sensitive data and/or samples: data aggregation, perturbation, and/or embargos 3) Ensure legal contracts for staff and researchers accessing samples and data include repercussions for contract violations and data leaks 4) Collect and share minimal data necessary 5) Include policy language in consents and public-facing outlets that highlight limitations of policy 6) Obtain Certificate of Confidentiality for all studies

Table 4.3 Summary of Study Findings and Recommendations Continued

Primary Findings	**Summary of Primary Findings** (Not a 1:1 association with Recommendations)	**Recommendations** (Listed in order of priority; Not a 1:1 association with Summary)
Research Effectiveness		
Impact of Research	• Questions raised about ability of research to be generalizable • Athletes question ability of research to identify differences at elite level if 'grit' not accounted for • Ability of research to be practical and useful questioned, often contrasted with 'just doing cool science' • Questions raised about what the common goal of research is • Mental well-being interventions may confound research findings	1) Standardize the scientific review process for all Alliance-funded research and secondary research that requires a scientific explanation of the study's generalizability and prioritizes studies with greatest potential impact 2) Engage athletes and mental health practitioners in the decision-making processes related to research activities, policies, and future uses of samples and data 3) Consider measuring grit and capturing metal health practices, such as breathing techniques and mindfulness, that may confound physical performance 4) Consider incorporating how return of results, if applicable, may impact research intervention outcomes 5) Consider enrolling participants across moonshot and innovation hub projects to maximize potential benefit to the athlete, to scientific discovery, and ensure Alliance resources are equally available to all participants

Table 4.3 Summary of Study Findings and Recommendations Continued

Primary Findings	**Summary of Primary Findings** (Not a 1:1 association with Recommendations)	**Recommendations** (Listed in order of priority; Not a 1:1 association with Summary)
Disparities	• Concerns that research of elite performance is seeking to create "master race," particularly when DNA collection and use • Athletes with less wealth may be more inclined to research participation to gain direct benefit • Importance of diverse research recruitment emphasized • Concerns voiced that commercial products from this research would only be affordable to extremely wealthy athletes • Need for equitable samples and data sharing with low-resourced researchers • Current research lacking for athletes in perinatal stage of life • Policies needs to be proactive to avoid harms and promote health equity • Opportunity for science to improve standards and regulations in sports	1) Create Alliance-wide policies addressing equitable access to research participation, requirements of studies to recruit representative samples, incentives for oversampling of historically underrepresented populations, and enhanced data protections for vulnerable and/or extremely small subgroups 2) Responsible use of race/ethnicity demographic factors and capture of upstream factors associated with social constructs 3) Develop strategic plan for equitable sample and data sharing such as hosting data and analytical tools centrally on a cloud-based server 4) Create an Alliance-wide policy that outlines appropriate and inappropriate uses of DNA, including when and how to report race/ethnicity in research findings 5) Provide and/or require researcher training related to potential ethical, legal, and social implications of HPR and include research ethics consultations for researchers intending to use DNA 6) Proactive measures to prevent misuse of research data 7) Consider providing participants with access to Alliance resources 8) Research should target under-researched areas, such as the perinatal athletes, and work to inform regulations to improve access to sports

Table 4.3 Summary of Study Findings and Recommendations Continued

Primary Findings	**Summary of Primary Findings** (Not a 1:1 association with Recommendations)	**Recommendations** (Listed in order of priority; Not a 1:1 association with Summary)
Direct Benefits		
Return of Results	• Most athletes anticipate, and many require, direct personal benefit from HPR participation • Return of individual results in exchange for HPR participation is generally expected • Generally, athletes desire study results from all research • Costs of research participation include time, energy, privacy, and possibly mental well-being and financial costs • Unclear whether research results would be necessary to disclose at team signing	1) Standardize what individual results would be appropriate to return to participants through Alliance, including legal assessment of duty to disclose 2) Standardize policies and support for return of individual results that may include medically necessary, incidental, and performance-related results. 3) Plan for adverse mental health impact of individual results, particularly when not actionable or not body-positive 4) Consider enrolling participants across moonshot and innovation hub projects to maximize potential benefit to the athlete, to scientific discovery, and ensure Alliance resources are equally available to all participants 5) Provide all participants with study-level results from primary and secondary research with enhanced dissemination that focuses on how information may be used to enhance personal performance 6) Consider giving participants early access to study results 7) When return of results is not possible, consider other forms of benefit sharing, such as utilization of Alliance-related resources or other meaningful direct benefits 8) Standardized consent language for studies that are and are not returning individual results to address possible therapeutic misconception of research

Table 4.3 Summary of Study Findings and Recommendations Continued

Primary Findings	**Summary of Primary Findings** (Not a 1:1 association with Recommendations)	**Recommendations** (Listed in order of priority; Not a 1:1 association with Summary)
<u>Commercialization</u>	• Athletes more empowered with sense of ownership of their samples and data • Interests expressed in profit-sharing for any commercial products that result from use of their information • Potential for legal disputes related to name, image, likeness (NIL) if research data is identifiable • Genetic modification/doping is an anticipated inevitability • Commercialization of research discoveries are expected to be cost-prohibitive to majority of the public and athletes	1) Create an Alliance-wide policy on commercialization of research activities and sharing with for-profit entities 2) Obtain legal consultation regarding limitations of ownership across states and international laws and applicability of NIL regulations 3) Consider profit sharing directly with participants as form of participation benefit 4) Consider requiring percentage of profits from all commercialization to fund additional community-relevant work, such as research for retired athletes' health 6) Create policies addressing potential for research to be classified as an enhancement 7) Build equity into product development 8) Include policy language in consents and public-facing outlets
Decision Making		
<u>Consent</u>	• Stakeholders emphasized need for athletes to be fully informed about research risks and benefits • Many athletes expressed desire to personally control how samples and data are used in secondary research • Many voiced interest in having more discreet choices over what samples and types of information were collected and how those related to research effectiveness • Many stakeholders felt it would be important for research consent to include athletes' trusted, inner-circles	1) Consider requiring dynamic consent for secondary research 2) Consider additional enhancements to the consent process for controversial research activities 3) Consider offering more choice and explanations in consent regarding sample and data collection 4) Incorporate athlete's trusted advisors into consent process 5) Provide training for consent process that incorporates consideration of power dynamics 6) Standardize consent and protocols to ensure consistent and transparent messaging and workflows

Table 4.3 Summary of Study Findings and Recommendations Continued

Primary Findings	**Summary of Primary Findings** (Not a 1:1 association with Recommendations)	**Recommendations** (Listed in order of priority; Not a 1:1 association with Summary)
Engagement	• Meaningful engagement with athletes is crucial and should include empowering them as partners and decision-makers related to how research is designed, conducted, and types of secondary research uses • Most important criteria for who is included in the decision-making process is that they are trusted by athletes • Players' associations should be a key stakeholder involved in engagement activities and primary driver of discussions with teams or leagues • Training staff and agents should receive educations about research as they are trusted advisors • Communication with athlete participants should include athlete input • Women and other underrepresented groups may need to be engaged separately in addition to larger group activities to ensure their needs are being met	1) Empower athletes in all facets of decision-making 2) Allow athletes to identify trusted resources who work in an advisory role 3) Whenever possible, include Players' Associations early in engagement process 4) Players' Associations should direct if team/league engagement is appropriate 5) Most protective accommodations should be applied to all participants, regardless of unionization 6) Education of non-athlete stakeholders necessary for research adoption 7) Proactively promotion of underrepresented voices should be built into engagement plan 8) Athletes should be included in reviewing and advising on all participant-facing and public-facing communications

Appendix

5.1 Methods Documents: Consent and Interview Guides

5.1.1 IRB Approved Consent

Key Informant Consent

You are being invited to participate in a research study titled "*Stakeholder Engagement for the Wu Tsai Human Performance Biobank*." This study is being conducted by Cinnamon Bloss, PhD and Julie Cakici, RN from the University of California - San Diego (UCSD). You were selected to participate in this study because you have been identified as a key stakeholder who may be able to help inform the research team about how the study should be designed and conducted.

The purpose of this research study is gain information about both your personal opinions and insights about the potential impact of this type of research, barriers and facilitators to conducting this research, and how the research team should engage with various stakeholders in the future to design the study. If you agree to take part in this study, you will be asked to participate in a one-hour interview. This interview will attempt to better understand how you think and feel about human performance research and who you think should be included in future discussions about how the study is conducted.

All interviews will be conducted via Zoom and recorded through Zoom. If you choose to remain on video during the interview, you will also be videotaped due to how the Zoom recording function works. All recordings will be transcribed and all identifying information (such as your name) will be removed, after which time, the recordings will be deleted.

There will not be any direct benefit to you from this research. If you complete the interview, you will be compensated $100 for your time. The researchers, however, may learn

more about how various stakeholders view human performance research and how best to engage these stakeholders in the future to help inform how this research should be conducted.

The research team will use information collected from this interview to inform future research activities. This information will be collected from other stakeholders who are interviewed and may be presented publicly (including, but not limited to, publications in journals, conference presentations, and news articles). It is important to note again that no identifying information about you will be released publicly.

There are minimal risks associated with this research study, including boredom, frustration, or discomfort related to interview questions, and there is a small chance for loss of confidentiality. You may choose not to answer any or all questions. Research records will be kept confidential to the extent allowed by law and may be reviewed by the UCSD Institutional Review Board.

Your participation in this study is completely voluntary. You may withdraw at any time by contacting Cinnamon Bloss at cbloss@ucsd.edu or Julie Cakici at jacakici@ucsd.edu. Choosing not to participate or withdrawing will result in no penalty or loss of benefits to which you are entitled.

If you have questions about this project or if you have a research-related problem, you may contact the researcher(s), Cinnamon Bloss at 858-534-9595 or via email at cbloss@ucsd.edu. If you have any questions concerning your rights as a research subject, you may contact the UCSD Human Research Protections Program Office at 858-246-HRPP (858-246-4777).

Consent reviewed prior to recording interview. Verbal consent obtained at the beginning of each interview once recording started.

5.1.2 Interview Guides

Interview Guide Questions (Athletes)

(Science/Technology in Sports)

I'm just curious about how you have experienced science or technology in your sport and your personal training.

- Have you ever been in a research study?
- What about others you know, have you heard about anyone being a part of a study?
- Have you seen technologies change over time?
- How do you feel about new tech or scientific recommendations?
- Do they last or are they fads?
- How have you seen technologies change over time? How do you feel about new tech or scientific recommendations?
- Do they last or are they fads?

(Human Performance Research)

What does "human performance research" mean to you?

So, as I mentioned during the consent, this new group of researchers trying to understand elite human athletic performance in detail. These researchers want to know exactly how athletes perform to help them customize their training- everything from what they should eat, how much sleep they need, to how they should recover. They are also interested in trying to predict as well as prevent injuries, and helping athletes heal faster. If you were asked to participate in this research, you would probably be asked to share your health information from your medical

record, take tests related to performance, undergo imaging tests, like an MRI, and provide samples by having your blood drawn or a muscle biopsy.

Do you have any questions about this information?

(Human Performance Research Outcomes/Facilitators)

In general, what do you imagine could be the impact of this kind of research?

- You
- Team
- Sports

What are the benefits you can imagine from this kind of research?

Probe:

- How do you think you could personally benefit from this kind of research?
- For example, could predicting your risk for injury be a benefit to you, and if so how?
- Would there have been a different kind of benefit for the team?
- Can you think of any benefits this might have on sports in general?

(Barriers)

Is there anything about this research that concerns you?

Probes

- Is there anything you would not want researchers to learn about you?
- Anything you would not want to know?
- For example, would you want to know about your future injury risks?
- If someone told you before you went pro that you would encounter many injuries over the course of your career, how might that have changed your future?
- Is there anyone you would not want to have access to your information?

- For example, what about if teams had access to that same injury risk information. Would that make a difference to you?
- Is there anything from this research that you would not want public or part of your player stats for example?
- How would you feel about injury risks becoming public information, like part of your player statistics?

The main strategy for supporting this kind of complex research is to gather and store all this information in a biobank. Biobanks can store and organize health information and samples, like blood and muscle tissue. Typically, the biobank will assign samples and information with a research ID and keep names and other identifying information separate. Previous biobanks have allowed researchers to share samples and information with other researchers all around the world. These other researchers may be asking different kinds of research questions than the researchers who collected the data to begin with. For example, they might analyze DNA or perform tests that haven't been invented yet. Since, biobanks remove the names from participants' samples and health information before they share it, they are allowed to share without needing to ask for permission each time another research was interested in using it. In that case, a participant would not be told about any of these other research studies. Also in this scenario, because these other researchers do not have the participant's name, they would not be able to tell them about what they learned in their study or give them any personal results.

Do you have any questions at this point or is there any additional information you would like to know (additional information will be provided if available at the end of the interview as part of a debrief)?

(Facilitators)

What are reasons why you would want to participate in a biobank?

- Tell me more about that/what you're thinking.
- Some people like the idea that a biobank makes it very easy to contribute to a lot of different kinds of cutting edge research. What do you think about this?

(Barriers)

What are reasons why you would not want to participate in a biobank?

- Would you be willing to have a muscle biopsy just for research purposes for example?

(Cohort Differences)

Over the course of your career, do you think your willingness to participate would have changed at different stages of your career path? If so, how and why?

(Stakeholder Identification)

Who would you want to consult with before deciding whether to participate in this type of research? For the purposes of our conversation today, please don't give me peoples' names, but rather just their relationship to you like "partner" or "parent."

As we have discussed, both human performance research and biobanks can be very complex. The research team thinks it is very important to have athletes involved in making decisions about how this new human performance research and new biobank are carried out. For example, the research team is curious about what, if any, changes are needed to make athletes more comfortable participating in this new research.

(Group Members)

Who do you think the research team should work with to make decisions about how athletes' samples and data are handled? Again, not peoples' names but which groups of people, such as "doctors" or "team owners."

(Group Dynamics/Functioning)

Imagine that a representative from each of the groups you just named would be asked to serve on a board that would advise the researchers on building this biobank. In your opinion, would these groups be able to work well together?

- Probes:

- Are there any tensions we should be aware of?
- Would researchers learn more from having everyone in one room or by talking to the different groups separately?
- Scenario?: I can imagine that team owners, for example, may want this research information in order to save money. How do you see business-related issues conflicting with athletes' concerns playing out if everyone is in the same room?

Debrief: I want to thank you again for sharing your thoughts with me. Your insights will be very helpful for the research team as they move forward in designing their studies. I also wanted to clarify again that the topics we discussed today are just hypothetical scenarios and that no decisions have been made yet about how these new studies will actually be conducted. Again, the purpose of this interview is to understand how you feel about how biobanks have been run in the past to help the researchers see where we may want to make changes and who they should talk to make sure any changes we make are helpful.

Unanswered Questions: I also wanted to take a few minutes to go back to some of your questions and concerns raised earlier and provide you with more information before we wrap up. <Answer questions as appropriate and clarify any misconceptions noted previously>

Follow-up questions:

Where there any questions that were confusing or difficult to answer? Or can you think of a better way for me to ask about this information?

Is there anything that I did not ask that you think I should be asking?

Demographics: I also need to collect your demographic information. We can do this right now together- it should take only a minute, or I can send you a survey link. Which would you prefer?

Wrap-Up: That's all that I have for us, but is there anything else you would like to share about this project?

Great. I will stop recording, but before you go, is there anyone you would recommend that we speak with?

Can you connect me with them?

Possible Additional Questions:

(Sports/Group Generalizability)

If another athlete was chosen to represent athletes' interests in this research, do you think that any of the following factors would affect their ability to represent your interests and if so, how?

a. Type of sport?- fairly interesting

b. Men's vs Women's sport? – required probing and rewording

c. Active vs retired athlete?- may require leading

d. Years of experience as a professional athlete?

e. Level/type of athlete? Such as an Olympian or minor league player? – good

d. Anything else?

(Organizational Characteristics/Power Dynamic)

Would your willingness to participate in this kind of research change based on who is telling you about it? For example, if the team was promoting this research versus if you were just approached by a researcher you did not know. – so far, everyone said increase in willingness to participate

Interview Guide Questions (*Non-Athlete Roles)*

(Science/Technology in Sports)

What have been your experiences with science or technology in sports.

- Have you ever been in a research study?
    - What about others you know, have you heard about anyone being a part of a study?
- Have you seen technologies change over time?
- How do you feel about new tech or scientific recommendations?
- Do they last or are they fads?
- How have you seen technologies change over time? How do you feel about new tech or scientific recommendations?

(Human Performance Research)

What does "human performance research" mean to you?

- What does it make you think of?

There is a new group of researchers trying to understand elite human athletic performance in detail. These researchers want to know exactly how athletes perform to help them customize training- everything from what they should eat, how much sleep they need, to how they should recover. They are also interested in trying to predict as well as prevent injuries, and helping athletes heal faster. If athletes that you work with were asked to participate in this research, they would probably be asked to share their health information, take tests related to performance, undergo imaging tests, like MRI's, and provide samples by having their blood drawn or a muscle biopsy.

(Human Performance Research Outcomes)

What do you think will be the impact of human performance research?

(Benefits/Facilitators)

What are the benefits you can imagine from this kind of research?

Probes:

How might you benefit from this research professionally?

How do you think the athletes you work with could benefit from this kind of research?

How might a team benefit from this research?

Would there be a benefit sports in general?

(Barriers/Risks)

Is there anything about this research that concerns you?

Probes:

- Is there anything you would not want researchers study?
- MD/Trainer/PT: What type of results would you want to see returned to athletes?
- What type of results would you want to see returned to clinicians like yourself?
    - How do you imagine you would use this information to treat your patients?
- Is there information that might be more sensitive that should have limited access?
    - For example, should teams have information about an athlete's injury risk information?
- Is there anything from this research that you would not want public or part of your player stats for example?
    - How would you feel about injury risks becoming public information, like part of a player's statistics?

The main strategy for supporting this kind of complex research is to gather and store all this information in a biobank. Biobanks can store and organize health information and samples, like blood and muscle tissue. Typically, the biobank will assign samples and information with a research ID and keep names and other identifying information separate. Previous biobanks have allowed researchers to share samples and information with other researchers all around the world. These other researchers may be asking different kinds of research questions than the researchers who collected the data to begin with. For example, they might analyze DNA or perform tests that haven't been invented yet. Since, biobanks remove the names from participants' samples and health information before they share it, they are allowed to share without needing to ask for permission each time another research was interested in using it. In that case, a participant would not be told about any of these other research studies. Also in this scenario, because these other researchers do not have the participant's name, they would not be able to tell them about what they learned in their study or give them any personal results.

Do you have any questions at this point or is there any additional information you would like to know (additional information will be provided if available at the end of the interview as part of a debrief)?

(Biobanking of Pro Athletes)

What are your thoughts about professional athletes participating in a research biobank?

(Benefits/Facilitators)

What are reasons why you would want athletes you represent to participate in this kind of research?

(Risks/Barriers)

What are reasons why you would not want athletes you represent to participate in this kind of research?

(Cohort Differences)

How do you think your recommendation for whether athletes should or should not participate in this kind of research might change based on where they are in their career?

Probes:

Do you think you would advise college athletes differently than professional athletes?

The research team thinks it is very important to have athletes involved in making decisions about how this new research is carried out. For example, the research team is curious about what, if any, changes are needed to make athletes more comfortable with participating in this new research.

(Group and Group Dynamics/Functioning)

Who, not peoples' names but which groups of people, such as "doctors" or "team owners," do you think the research team should work with to make decisions about how athletes' samples and data are handled?

In your opinion, would these groups be able to work well together?

- Probes:

Are there any tensions we should be aware of?

Would researchers learn more from having everyone in one room or by talking to the different groups separately?

Debrief: I want to thank you again for sharing your thoughts with me. Your insights will be very helpful for the team as they move forward in designing their research studies. I also wanted to clarify again that the topics we discussed today are just hypothetical scenarios and that

no decisions have been made yet about how these new studies will actually be conducted. The purpose of this interview is to understand how you feel about typical biobanks and help the researchers see where we may want to make changes. Similarly, we want to know who we should talk to while we're designing these studies to make sure any changes we make are helpful.

I also wanted to take a few minutes to go back to some of your questions and concerns raised earlier and provide you with more information before we wrap up. <Answer questions as appropriate and clarify any misconceptions noted previously>

Demographics

I just need to get some demographic information from you. It should only take a minute, or I can email it to you if you would rather.

That's all that I have for us, but is there anything else you would like to share about this project? Or would you like to provide additional information about something we already discussed?

Is there anything else that you think I should be asking about?

Was anything unclear? Or is there a better way to ask any of these questions for this group?

Lastly, we are trying to get a wide variety of people involved in professional sports in the US**.**

Possible Additional Questions:

(Sports/Group Generalizability)

If another <stakeholder role> was chosen to represent <stakeholder group's> interests in this research, do you think that any of the following factors would affect their ability to represent your interests and if so, how?

a. Type of sport?

b. Men's vs Women's sport?

c. Title?

d. Years of experience?

e. Level/type of sport? Such as an Olympics or minor leagues?

d. Anything else?

(Nature vs Nurture)

Based on your experience working with many athletes over the years, what do you think makes a professional athlete stand out from everyone else who plays the sport?

- Probe: How much of a role do you think natural talent or ability had to do with their success versus hard work and determination?

5.2 White Paper Appendix Materials

Recruitment:

This study recruited professional athletes in the United States whose incomes required regular competition, be it via tournaments or team games. Athletes whose salary primarily consists of sponsorship opportunities, including Olympians, were excluded as the differences in context are believed to require a separate assessment. Of note, several athletes who met the definition of professional athlete for this study also were Olympic athletes. Similarly, many professional athletes who competed regularly in individual sport competitions also received endorsements. Where applicable, these experiences are included in relevant summary sections.

Recruitment of professional athletes was balanced between men and women, included active and retired athletes, and represented a wide range of both team and individual competitive sports. Non-athlete stakeholders included agents, team staff, medical and training staff, lawyers, player's association representatives, and human performance researchers. Athletes who had experience in non-athlete stakeholder roles, such as coaches, agents, and physicians, were prioritized for recruitment as key informants. Recruitment required leveraging associations within the Alliance's network and amongst the participants themselves. Diverse points of view and lived experiences were sought throughout the recruitment process.

Interviews:

Semi-structured interviews were conducted with 42 individuals with most interviews lasting one hour. This study introduced the topics of human performance research and biobanking separately to minimize conflation of HPR with how a biobank operates. Therefore, the participants often spoke about human performance research alone and at other times spoke about biobanking under the umbrella of HPR. Therefore, recommendations made herein are

anticipated to impact Wu Tsai Human Performance Research Alliance members more broadly than the biobanking researchers alone. Study materials available upon request.

Public Disclosure

This White Paper is intended to address Alliance-specific matters, but it is also intended to be published to assist other researchers conducting Precision Health and/or biobanking research with elite athletes in making data-driven decisions. The summary of study results in this White will be expanded and reported a separate manuscript that will be submitted for peer-reviewed publication. This manuscript will provide more specific results, including direct quotes, and will discuss the impact of these findings as they relate to the current literature more broadly. Furthermore, this research has been conducted as part of the primary author's doctoral dissertation, which includes the White Paper, results manuscript, and additional study-related information. The full dissertation will be made be publicly available in accordance with the University of California San Diego and San Diego State University policies.

5.3 IRB Protocol

UCSD Human Research Protections Program

New Application

RESEARCH PLAN: Version date: 9/30/2013

1. PROJECT TITLE

Stakeholder Engagement for the Wu Tsai Human Performance Biobank

2. PRINCIPAL INVESTIGATOR

Cinnamon Bloss, PhD

Professor and Interim Assistant Dean, Academic Affairs

Herbert Wertheim School of Public Health and Human Longevity Science

Director, Center for Empathy and Technology

Associate Director, T. Denny Sanford Institute for Empathy and Compassion

University of California, San Diego

Co-PI

Julie Cakici, RN

Graduate Student Researcher

School of Public Health

3. FACILITIES

Locations for this research include:

• UC San Diego campus: data storage

• Virtual (e.g., over the phone, online)

• Throughout United States

4. ESTIMATED DURATION OF THE STUDY

10 Years

5. LAY LANGUAGE SUMMARY OR SYNOPSIS (no more than one paragraph)

This study will inform the creation and maintenance of the Wu Tsai Human Performance Research Biobank that will be housed at UCSD. The researchers in the Wu Tsai Human Performance Alliance seek to explore human performance of elite performers (such as professional and elite athletes, elite military personnel) as well as lay populations and those whose performance may be hindered (such as older adults, those undergoing surgery for injuries). This study will begin by interviewing key informants from the various cohorts of interest to advise the research team about barriers and facilitators of a multiomics biobank researching human performance, expectations of human performance research, and about how to best engage with the various stakeholders within their cohort to inform the design and conduct of the biobank. The information collected from these interviews will guide the creation of forums for stakeholder engagement, such as community advisory boards, town hall meetings, etc. In the future, it is planned that the next phase of this study will conduct engagement activities to explore the appropriateness and acceptability of traditional biobank processes and policies.

6. SPECIFIC AIMS

Key Informant Interviews

Specific Aim 1: Assess attitudes and beliefs toward participating in multiomics biobanking and research on human performance among key stakeholders (athletes, coaches, managers, non-athlete patients who may donate samples, and other experts).

Specific Aim 2: Explore the potential conflicts of interest and power dynamics between key stakeholders to inform the recruitment, conduct, and policies required for future community

engagement activities, such as a Community Advisory Board, that ensure equitable representation of stakeholder views.

7. BACKGROUND AND SIGNIFICANCE

Dynamic and authentic community engagement has been shown to be key for the successful creation and implementation of biobanking research.1-4 This study will partner with the new Wu Tsai Human Performance Alliance's (WTHPA) Biobank at UCSD to engage with the various prospective cohorts of participants in order to improve acceptability and accessibility of this cutting edge multiomics, health performance research. Precision sports-medicine carries numerous potential benefits to both elite and amateur athletes as well as for the general public.5,6 The new Wu Tsai Human Performance Alliance's (WTHPA) Biobank at UCSD seeks to comprehensively study a wide variety of athletes to help "optimize human performance and transform human health on a global scale."7 To do this, six research sites will be studying peak performance of athletes and other cohorts with a range of abilities: professional and elite athletes, college athletes, child athletes, elite military personnel, older adults, and the general public.8 The research team at UCSD will be creating and maintaining the biorepository for the samples and data collected as a part of this project. However, it is expected that each of these various cohorts face different ethical issues, barriers and facilitators to participation in non-invasive and invasive biosampling and multiomics biobank research.5,9-14 Furthermore, research on human performance will involve numerous stakeholders who, although peripheral to the potential participants, are expected to have enormous influence on participation, particularly amongst elite performers.15 The stakeholders will vary within each cohort, but it is expected that power-dynamics (e.g., parent and child, team physician and player, etc.) and existing relationships between stakeholders (e.g., team owners and player unions, agents and players, etc.) will also

influence the discussion and ultimate successful implementation of a multiomics biobank in these cohorts. In order to conduct such stakeholder engagement events, the power dynamics between various stakeholders and potentially conflicting expectations about research outcomes must be explored to inform how the CAB should function to ensure equitable representation of stakeholder voices, particularly the athletes themselves.16,17

Community engagement is especially critical for populations for whom the risk for participation is greater than the general public.11,18 Elite athletes in the US would likely incur greater risks from participating in a multiomics biobanking research than traditional biobank participants from the general public.11 For example, professional athletes may require higher protections for privacy and data/sample governance than the general public due to their celebrity status and increased risk for discrimination.5,9,11,15,19,20 Similarly, other stakeholders, such as team owners, managers, coaches, and physicians, may have expectations about the conduct and outcomes of human performance research that conflicts with professional athletes' self-interest.11 Therefore, to develop a successful multiomics biobank that includes a professional athlete cohort, it is critical that the researchers identify the key stakeholders, plan to engage regularly and work together with those stakeholders to adapt the biobank to be both more acceptable and accessible for professional athletes.

Furthermore, little is known about the attitudes and beliefs of elite athletes and those related to human performance and multiomics research in the United States. Although there is some data about elite athletes' opinions on genetic testing for sports performance and injury prevention, the two existing studies include a very small number of US athletes and are not likely to include athletes' or support staff opinions from major US sports.6,21 Through key informant interviews, this study will also explore attitudes towards multiomics biobanking and research

participation along with stakeholders' willingness to participate in various research activities, including engaging with the researchers to inform how the biobank should operate. Similarly, we will use key informant interviews of the various stakeholders to explore the existing power dynamics, expectations related to research outcomes, and possible ways to mitigate anticipated conflict to direct the composition, conduct, and procedures of the engagement activities.22-24

8. PROGRESS REPORT

N/A

9. RESEARCH DESIGN AND METHODS

This study plans to assess the ethics, stakeholder perceptions, and modifications to traditional biobanking processes requested from stakeholders to inform research practices. The study's methods will incorporate Dissemination and Implementation (D&I) Science best practices to evaluate the organizational and individual contexts that affect implementation and research outcomes (such as successful recruitment) and will be assessed throughout the implementation process.25 The characteristics of stakeholders (including the biobank researchers) and their perceptions of the biobank will be captured to understand the complex context in which these individuals and organizations are situated with respect to the implementation of a multiomics research biobank. Similarly, successful community engagement and implementation of multiomics biobanking research will likely require adaptations (such as changes in policies regarding data and sample governance or consent) to traditional, standard biobanking processes in order to improve acceptability of the biobank. D&I Science provides validated measures and methodologies to capture and analyze themes and adaptations raised by various stakeholders.26,27 Despite multiple studies reporting utilizing community engagement efforts to inform biobanking practices, there continues to be a lack of measurement of the impact

of engagement activities.28 Dissemination of the empirical data collected from this study can help to validate (or invalidate) bioethical speculation, inform future community engagement efforts, add to the literature related to stakeholder perceptions of multiomics biobanking, and inform policies and procedures in other biobank settings.28 The PRISM and RE-AIM frameworks will be used to identify contextual factors that impact implementation of a biobank along with a deductive approach based on grounded theory.25,29

This study will recruit key informants from the various cohorts targeted for enrollment into the WTHPA Biobank. Key informants will be identified as individuals who can offer greater depth of information due to their position in their community. For the first phase of this study, key informants of stakeholders who are associated with professional athletes be recruited. Stakeholders who have experience in more than one stakeholder group, such as agents who used to be athletes, or those believed to provide either a unique depth of understanding, such as those with medical or legal backgrounds, or perspectives will be targeted for recruitment. Retired and active professional athletes will be asked to identify key stakeholders that the research team should work with to design research practices for this cohort. These stakeholders will likely include team management, trainers, agents, union representatives, and their family members.

Key informants will be interviewed to assess barriers and facilitators towards conducting human performance biobanking research within their cohort. These key informants will also provide the research team with insights into potential conflicts of interest and the best way to engage their community and how such engagement may need to be tailored to ensure the potential participants' voices are not lost amongst the other stakeholders'. The interview guide for each cohort will be piloted and iteratively adapted to ensure the questions are understandable, face valid, and that the interviews can be completed in approximately one hour. Semi-structured

interviews will be conducted by trained research staff via Zoom or in-person (if in-person interviews become safe in the future). Each interview is anticipated to last one hour. Due to the recording function in Zoom, both video and audio will be recorded. However, the video recording will be deleted, and the audio will be transcribed by an outside service (Rev.com). Demographic data will be collected from participants at the time of the interview and will be stored in REDCap.30,31 We have included slides in the event that our pilot tests find having the visual anchors are more helpful, but these slides may not be used on any or all participants.

All transcripts will be reviewed by research staff for accuracy and any identifying information will be redacted. Transcripts will be systematically coded following common methods in qualitative coding.32-34 Analysis will employ a hybrid approach that includes inductive coding using a priori themes from the genomic biobanking literature as well as constructs from the PRISM and RE-AIM frameworks along with a deductive approach based on grounded theory.25,29,35-38 Coding will be primarily led by Julie Cakici as a part of her dissertation. The dictionary will be created via an iterative review of transcripts in collaboration with Dr. Cindy Schairer, a qualitative methods expert. In the event Dr. Schairer and Ms. Cakici are unable to reach consensus on coding, Dr. Bloss will be included in the process to help achieve consensus. Coding will be done in a qualitative research software package such as Atlas.ti or QDA Miner.39,40

10. HUMAN SUBJECTS

This study will recruit individuals determined to be members of or stakeholders to one or more of the following cohorts: professional, Olympic, and/or college athletes, military personnel, older adults, those requiring surgery for musculoskeletal injuries, and/or the general public. Participants will be assigned unique research identifiers. Pregnant women and prisoners

(specifically those released from custody but still monitored by the state) may incidentally be enrolled, but no research activities are targeted towards these protected populations. Pilot testing of interview guides will be conducted using convenience sampling of local stakeholder proxies (such as college athletes, UCSD training staff, etc.).

11. RECRUITMENT AND PROCEDURES PREPARATORY TO RESEARCH

Purposive sampling will be used to recruit stakeholders from the various cohorts (e.g., professional athletes, college and Olympic athletes, military personnel, child athletes, older adults, and the general public) for key informant interviews.41 Stakeholders will be identified from the literature, research team member experiences, and via key informant interviews of the primary cohort. In the case of professional athletes (the first primary cohort), active and retired athletes that represent men's and women's sports will be recruited. The study will also seek to include both team-sports and individual sports to inform how future community engagement recruitment and activities should be balanced. A priori stakeholders for this cohort include agents, union representatives, family members, team managers, owners, physicians, and trainers. Stakeholders who represent more than one group, such as coaches who were athletes, will be prioritized for their increased depth of knowledge. Priority will also be given to those who have unique qualifications that are believed to enrich the data collected (e.g., stakeholders with medical or law degrees), those believed to be at a higher risk for participation in multiomics, human performance research biobanking (e.g., professional athletes or those from underrepresented groups), or those recommended by researchers, community members, or other stakeholders. The research team may also identify potential key informants via snowball recruitment and convenience sampling for groups that are more difficult to recruit, such as professional athletes. Recruitment strategies may vary for the different cohorts and stakeholder

groups. Other researchers from the WTHPA may be leveraged to invite stakeholders to participate in this study on our behalf.

The first phase of this study will recruit 40- 60 key informants comprised of professional athletes, their agents, union representatives, team management, team physicians or trainers, and/or other key stakeholder groups identified by the professional athletes. Recruitment will be balanced by men's and women's sports and will represent team sports and individual sports. Recruitment may be concluded prior to enrollment of 60 participants based on data saturation.

Inclusion Criteria: Be in a cohort that may be recruited to participate in biobanking research, or in a stakeholder group related to a cohort.

Exclusion Criteria: Be unable or unwilling to provide informed consent or assent when applicable.

12. INFORMED CONSENT

Participants being interviewed will be consented prior to their interviews. Signed consent will not be obtained to minimize the amount of identifying information collected and stored for this cohort. A verbal consent will be captured at the beginning of the interview process. Participants will be notified that questions, comments, topics discussed, recommendations, etc. as well as general information about the community member speaking, such as estimated age, gender and any self-identified role (parent, potential participant, etc.) will be collected, evaluated, and shared for research purposes.

13. ALTERNATIVES TO STUDY PARTICIPATION

The alternative to participation is to not participate. Participants may decline participation in interviews without any penalty or loss of benefits.

14. POTENTIAL RISKS

Potential risks to participants include: 1) loss of confidentiality; and 2) potential for participants to experience stress, embarrassment, frustration, discomfort, fatigue and/or boredom in answering questions in the interviews. We currently believe that these risks are of low likelihood given our prior experience conducting interview research.

15. RISK MANAGEMENT PROCEDURES AND ADEQUACY OF RESOURCES

Research information will be stored in REDCap and/or in a password protected UCSD shared drive with access to both limited to study staff. All participants will be assigned a unique research ID. No identifying information will be used in the reporting of study results. Participants will be allowed to skip any or all questions that are uncomfortable for them. Participants will be informed that participation in the research is voluntary, and they may withdraw at any time.

Interviews will be conducted at a time chosen by the participants via UCSD's Zoom platform. Interviewees will be advised of recording prior to the start of recording and informed that they may turn off their video if they wish. Video recording will only be incidental and no images will be used from this study. We will use Rev.com for transcription services. Rev.com takes maximum precautions to secure the safety and security of all client documents. They keep client information and documentation private. The transcriptionists are held to strict nondisclosure agreements and viewing of documents is limited to a need-to-know basis.

16. PRIVACY AND CONFIDENTIALITY CONSIDERATIONS INCLUDING DATA ACCESS AND MANAGEMENT

Names will only be collected for the purpose of identifying, recruiting, scheduling, and tracking eligible participants and for remitting payment upon completion of eligible research

activities. All participants will be assigned research IDs and will be identified in publications by their cohort, stakeholder group, and other relevant demographic descriptors (such as men's vs women's sports or active vs retired).

17. POTENTIAL BENEFITS

This study will help inform how samples and data are collected, stored, and shared for future research purposes and changes made to those processes and policies may directly benefit their and other cohort members that choose to participate in biobanking research in the future. Data from this study will also add to the growing literature about human performance research, community engagement, and multiomics biobanking procedures. Participants may find it gratifying to share their experiences for the benefit of improving research processes.

18. RISK/BENEFIT RATIO

The risks presented are minimal, while the benefit to society is moderate.

19. EXPENSE TO PARTICIPANT

Participants' potential expenses include costs associated with time related to participation in research activities.

20. COMPENSATION FOR PARTICIPATION

Participants will be compensated up to $100 per interview.

21. PRIVILEGES/CERTIFICATIONS/LICENSES AND RESEARCH TEAM RESPONSIBILITIES

Cinnamon Bloss, PhD, Professor, Herbert Wertheim School of Public Health, UCSD. Dr. Bloss will serve as the Principal Investigator (PI) of this study and will oversee all staff and research activities.

Julie Cakici, RN, Doctoral Student in the Joint Doctoral Program in Public Health, UCSD & SDSU. Ms. Cakici will serve as a Co-Primary Investigator of this study and will oversee all aspects of this study. Specifically, Ms. Cakici will conduct interviews, collect and analyze data, lead manuscript development, and oversee additional research staff.

Samuel Ward, PT, PhD Vice Chairman, Orthopedic Surgery and Professor, Radiology. Dr. Ward will serve as a co-investigator. Dr. Ward is one of the lead investigators overseeing the Wu Tsai Human Performance biobanking research. Dr. Ward assist with all aspects of this study.

Severin Ruoss, PhD, Postdoctoral Scholar, Orthopedic Surgery. Dr. Ruoss is a co-investigator with Dr. Ward and will also advise on this project and assist with data analysis and interpretation.

Cynthia Schairer, PhD, Family Medicine & Public Health, UCSD. Dr. Schairer may conduct interviews, collect and analyze qualitative data.

Cynthia Triplett, MPH, MA, Calit 2, UCSD. Ms. Triplett will provide project management support for the study and process participant payment. Ms. Triplett may also conduct data collection and analysis.

Kyle Brothers, M.D., Ph.D. is an Associate Professor in the Department of Pediatrics at the University of Louisville. Dr. Brothers is an expert in biorepository ethics and will serve as a consultant for this project. As a consultant, he will assist with study design, results interpretation, and manuscript development.

Students: Undergraduate and graduate students may be included in the qualitative analysis of de-identified transcripts and engagement documents. Any student assisting with qualitative data analysis will be trained and supervised by Ms. Cakici or Triplett or Dr. Schairer.

22. FUNDING SUPPORT FOR THIS STUDY

This study is funded by the Wu Tsai Human Performance Alliance. The fiscal contact is Marla Sklover (msklover@eng.ucsd.edu).

23. CONFLICT OF INTEREST

None to report.

24. PROTOCOL BIBLIOGRAPHY

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