Title

Youth Sports Specialization and Its Effect on Professional, Elite, and Olympic Athlete Performance, Career Longevity, and Injury Rates: A Systematic Review

Journal

Orthopaedic Journal of Sports Medicine, 10(11)

ISSN

2325-9671

Authors

McLellan, Maddison
Allahabadi, Sachin
Pandya, Nirav K

Publication Date

2022-11-01

DOI

10.1177/23259671221129594

Peer reviewed

Youth Sports Specialization and Its Effect on Professional, Elite, and Olympic Athlete Performance, Career Longevity, and Injury Rates

A Systematic Review

Maddison McLellan,* BA, Sachin Allahabadi,†‡ MD, and Nirav K. Pandya,† MD

Investigation performed at University of California, San Francisco, San Francisco, California, USA

Background: Limited data are available on the long-term consequences of early sports specialization in high-level athletes.

Purpose: To evaluate the existing literature on the effects of sports specialization among professional, Olympic, and other elite athletes.

Study Design: Systematic review; Level of evidence, 3.

Methods: We performed a systematic review of studies from 1990 to 2021 on youth sports specialization in professional, elite, and/or Olympic athletes following PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines. An elite athlete was defined as one who performed at the highest level of his or her sport, beyond college level. Data were summarized according to 6 objectives: (1) definitions of specialization, age at specialization, and participation in other sports; (2) motivation for specialization; (3) athlete perspectives on specialization; (4) performance data; (5) specialization and injury risk; and (6) career longevity.

Results: From 8756 articles, 29 studies were included, of which 17 (58.6%) were survey-based studies. Of the 8 articles that commented on injury risk, all demonstrated reduction in injury risk in athletes who delayed specialization. Performance benefits were apparent with later specialization in 7 of 9 articles; the remaining 2 showed benefit with earlier specialization in marathon runners and soccer players. There were less definitive results on career longevity, with 5 of 9 articles finding no association between career longevity and sports specialization.

Conclusion: Although current data on sports specialization in elite, professional, and Olympic athletes are mostly retrospective and survey-based evidence, most sports demonstrate better performance after youth multisport engagement, and youth sports specialization was linked with increased injury risk in athletes at the highest levels of competition.

Keywords: elite; Olympic; pediatric sports medicine; professional; sports specialization

Youth athletes have begun specializing, or pursuing "year-round [8+ months per year] intensive training in a single sport at the exclusion of other sports," at earlier ages.[5,19,29] Incentives for early sports specialization include the labels of child prodigy or gifted, the pursuit of college scholarships and sponsorships, and the hope of attaining Olympic, elite, or professional status.[4,35,41,43] In turn, youth sports have become increasingly competitive and professionalized, often driven by parents and coaches.[5,11,20] Expectations for child athletes entail participating on multiple teams at the community, club/competitive, and school levels.[32] This can be associated with overtraining, causing sport-related injuries and health problems such as overuse injuries and burnout.[5,16,32,53] Other risks and negative consequences of sports specialization include social isolation, high individual and economic cost, overdependence, quitting sports at a young age, and compromised growth and maturity.[1,3,27,28,32,35,38] Given these negative mental and physical health consequences, multiple medical organizations, including the American Orthopaedic Society for Sports Medicine (AOSSM),[51] American Academy of Pediatrics (AAP),[10] the American Medical Society for Sports Medicine (AMSSM),[15] and the American College of Sports Medicine (ACSM), have all released statements expressing concern about early specialization.[32]

The Orthopaedic Journal of Sports Medicine, 10(11), 23259671221129594
DOI: 10.1177/23259671221129594

Despite popular belief, early sports specialization has not been validly linked to professional athletic success and, in fact, it has been shown that late adolescent (compared with childhood) specialization and broader training in childhood are linked to more elite achievement.[27,37] The body of work on sports specialization in high-level athletes collectively suggests that early specialization is not necessary to meet the expectations of many elite or professional sports. However, this is not the case with all sports, particularly those with young average ages of competitors.[27,32,37] For example, studies on ice skating, gymnastics, and dance have found that early specialization is imperative for elite status, as peak competitive levels tend to come before full maturity is achieved.[32]

There is pressure to specialize in sport so youth athletes can "make it big," despite controversy whether early specialization is required for elite athletic status.[11] Studies have found early specialization to be detrimental to elite athlete success due to effects on injury and career length.[32,37] For example, previous studies have found that early specialization is associated with a higher rate of upper extremity injuries in throwers, injuries attributed to specialization, and fewer games played in Major League Baseball (MLB).[12,14,52] Similarly, a study of National Basketball Association (NBA) players found that those who played multiple sports in high school were less likely to sustain major injuries and had increased longevity compared with those specializing early.[46] While these works highlight some of the potential negative consequences of sports specialization, information on the effects of sport specialization among elite-level athletes is still limited.[35]

The purpose of this systematic review was to evaluate the literature on the effects of sports specialization amongst professional, Olympic, and elite athletes.

METHODS

This systematic review was registered on the International Prospective Register of Systematic Reviews (PROSPERO). A search was performed in September 2021 on PubMed and Embase databases and evaluated for studies from 1990 to 2021 on youth sports specialization in professional, elite, and Olympic athletes. The following search terms were used: ("sports specialization" OR "youth" OR "specialization" OR "youth sports injuries") AND ("professional" OR "elite" OR "Olympic"). PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines were followed.

Studies were included if they discussed youth sports specialization in professional, elite, or Olympic athletes. Studies were required to have full-text availability in the English language. Exclusion criteria were narrative or systematic review articles, commentaries, editorial pieces, or those that did not distinguish data specific to the high-level athletes (defined as at the professional, elite, or Olympic level). Collegiate-level athletics and elite youth athletics were excluded as the aim of the study was to evaluate career success at the highest levels of play; we included only postcollegiate athletic participation at the highest sport level ("elite"), Olympic, or professional level. Participation in competition at these levels was defined as "long-term success." References from each study and reviews found in the search were evaluated.

The review process involved a multistage screen from titles to abstracts and ultimately full-text articles. It was performed by 2 independent authors, a medical student (M.M.) and a senior orthopaedic resident (S.A.). Throughout the process, disagreements on exclusion/inclusion were reconciled by a third reviewer, a senior pediatric orthopaedic surgeon specializing in sports medicine (N.K.P.). Initial exclusion based on title was independently performed by the 2 reviewers. Duplicated articles were omitted in initial screening. Abstracts were then screened and agreed-upon abstracts were included in full-text review. Any article suggested by either reviewer underwent full-text review.

Data were compiled for qualitative analyses. Aggregated data were summarized as numbers or percentages of articles meeting a particular objective. Because substantial heterogeneity existed in the reported data, no formal summary data were generated for specific outcomes. Each article was evaluated for methodological quality using the Methodological Index for Nonrandomized Studies (MINORS).[49] Data were summarized by the following objectives: (1) definitions of specialization, age at specialization, and participation in other sports; (2) motivation for specialization; (3) athlete perspectives on specialization; (4) performance data; (5) specialization and injury risk; and (6) career longevity.

RESULTS

A total of 8756 articles were initially identified to be considered for review after removing duplicates; of these, 29 articles met the final inclusion criteria and were included for evaluation (Figure 1).[§] Of these articles, 17 (58.6%) were survey-based studies.[‖] Descriptions of each study are shown in Appendix Table A1. The median MINORS score for the studies was 7 (Appendix Table A2).

[§]References 2, 6–9, 11–14, 18, 22–26, 30, 31, 33, 34, 36, 37, 40, 42, 44–46, 48, 50, 52.

[‡]Address correspondence to Sachin Allahabadi, MD, Department of Orthopaedic Surgery, University of California, San Francisco, 500 Parnassus Avenue, MU 320-W, San Francisco, CA 94143, USA (email: sachin.allahabadi@gmail.com) (Twitter: @sach_MD).

*School of Medicine, University of California, Irvine, Irvine, California, USA.

†Department of Orthopaedic Surgery, University of California, San Francisco, San Francisco, California, USA.

Final revision submitted August 1, 2022; accepted August 7, 2022.

One or more of the authors has declared the following potential conflict of interest or source of funding: N.K.P. has received education payments from Evolution Surgical and consulting fees from OrthoPediatrics. AOSSM checks author disclosures against the Open Payments Database (OPD). AOSSM has not conducted an independent investigation on the OPD and disclaims any liability or responsibility relating thereto.

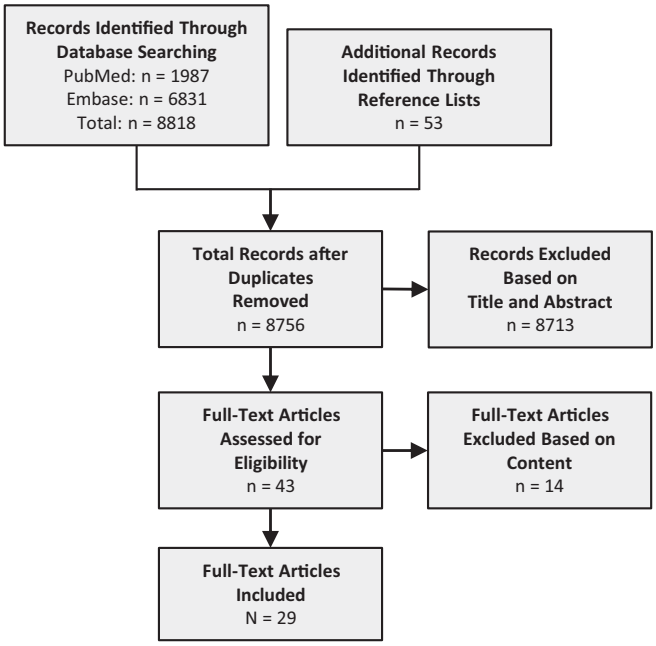

Figure 1. PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) flowchart for study inclusion, demonstrating 29 studies included.

Definition of Terms

Variable definitions of sports specialization were utilized; in total, 12 articles explicitly defined sports specialization.[¶] Common definitions of specialization included early involvement in the main sport, normally occurring in early-to-middle childhood, with little or no involvement in other sports[37]; playing 1 sport exclusively and intensely before age 12[18]; and intense year-round training in a single sport at the exclusion of other sports.[46]

Motivation for Specialization

Of the 29 articles included in this study, 6 explicitly discussed athletes' motivations for sport specialization.[6,12,13,18,31,36] In professional baseball players, 1 study found that 44% of 708 survey respondents reported that they personally made the decision to specialize, while 26% indicated that another person was more important in their decision to specialize.[18] Among the players who specified that they had been influenced to play by another person, the greatest number (n = 111; 16% of total respondents) attributed their motivation to their fathers, 3% (n = 22) to their mothers, 3% (n = 20) to their coaches, and the remaining 3% (n = 27) named a grandparent, a teacher, or another relative or friend.[18] Another study regarding professional baseball players found that love or enjoyment for the sport was the most popular reason for specialization (34.5%), followed by professional opportunities (15.8%), because the sport was the one the player was best at (12.5%), collegiate scholarship aspirations (12.1%), to be the best (9.6%), time/schedule conflicts (6.0%), to improve in the sport (4.8%), or advice of a coach and/or parent.[12] Relative to data in professional baseball, a higher proportion (95%) of National Hockey League (NHL) players in another survey reported self as the motivation behind their decision to specialize in ice hockey.[6] Other reasons listed included parent and wife.[6] In a study surveying Major League Soccer (MLS) players, most popular reasons to specialize included focus on soccer (88%), lack of time (16%), afraid of getting hurt (6%), quit other sports on coach recommendation (5%), or injury (2%).[31] In addition, in elite wrestlers, the majority of athletes (55%) reported that they were self-motivated to specialize, followed by 26% who were encouraged by a parent or guardian, and 15% who were encouraged by a coach.[36] Similar to the other studies, elite weightlifters were largely self-motivated to specialize, which occurred at both junior (≤16 years) and youth (17-20 years) levels.[13]

Athlete Perspectives on Specialization

Six articles explicitly discussed the thoughts these elite, professional, and Olympic athletes had on sports specialization now that they were at the top level.[7,11-13,36,44] In a survey of professional women ice hockey players, 91% of players reported feeling that their participation in other youth sports had positively affected their ice hockey career and none of the athletes felt as though playing other sports had detracted from their ice hockey career.[7] In a survey of MLB players, over half of non–US-born MLB players would want their children to specialize in a single sport; in contrast, less than 10% of US-born MLB players want their children to specialize (55.4% vs 7.1%, respectively; $P < .001$).[12] A survey of US Winter and Summer Olympic athletes from 2000 to 2012 found that 59.6% thought that playing several sports was very valuable in athletic development.[44]

On the other hand, the majority (61.7%) of professional MLB and NHL athletes in a 2015 to 2016 survey indicated they believed specialization helps athletes play at a higher level. However, only 22.3% of these athletes said they would want their own child to specialize to play only 1 sport during childhood/adolescence.[11] In elite wresters, a survey found that just less than half of respondents (43%) felt that early specialization was required to become an elite-level wrestler.[36] Similarly, a survey of elite weightlifters found that a majority of athletes (68.8%) felt that specializing during youth was not necessary to achieve elite status.[13]

Performance Data

Specialization Not Beneficial. Nine articles discussed the relationship between early sport specialization and athlete performance.[#] A study on elite CGS (centimeters, grams, or seconds sports) athletes found that athletes who had fewer accumulated practice hours by age 15 and more

[¶]References 6, 11, 12, 14, 18, 22, 31, 37, 45, 46, 50, 52.

[#]References 6, 9, 14, 23, 31, 37, 40, 46, 50.

practice hours by age 18 had increased international success.[37] In elite hockey players, there was no difference between Division 1, Division 3, and NHL athletes in terms of age of specialization, suggesting that age of specialization did not play a role in the overall level of play the athletes achieved.[6] Similarly, in a study of first- and second-round National Football League (NFL) draft picks, there was no difference in proportions of athletes going to the Pro Bowl based on high school multi- versus single-sport participation.[50] In a survey of MLB athletes, athletes who played multiple sports in high school played in significantly more mean total games (362.8 vs 300.8; $P < .01$) as well as more mean MLB games (95.9 vs 71.6; $P < .04$) than single-sport athletes.[14] Similarly, a survey of NBA players found that players who were multisport high school athletes competed in a significantly greater percentage of total games compared with single-sport high school athletes (78.4% vs 72.8%; $P < .01$).[46]

In a study of athletes who appeared in the Olympics in 1999 and 2002, athletes involved in other sports had a significantly higher success rate than those involved in just their sport.[23] Several articles discussed track performance in the context of early specialization. In a study comparing International Association of Athletics Federation (IAAF) under 18 years (U18) and senior World Championship appearances, on average, only 17% of the male athletes and 21% of the female athletes were in the top 50 rankings in both the U18 and the senior categories, and those who were in the U18 groups had less consistent improvement and performances relative to the senior-only groups; ultimately, later age was related to improved peak performance.[9]

Specialization Beneficial. On the other hand, some studies did demonstrate success with specialization.[31,40] In a survey study of active MLS players, it was found that MLS athletes who had previously received a college scholarship ($P = .02$) specialized at a significantly younger age.[31] Furthermore, in a study comparing African versus non-African elite marathon runners, the young specialization group was found to have significantly higher rates of improvement than the median and older specialization groups.[40] In addition, the young specialization group had significantly faster at-peak marathon performance than both the median and the older specialization groups.[40]

Specialization and Injury Risk

Eight articles included in this review explicitly discussed injuries in relation to sports specialization.[11-14,36,46,50,52]

In the NBA, athletes who competed in multiple sports in high school were less likely to sustain a major injury during their career compared with those who competed in a single sport in high school (25% versus 43%; $P = .03$).[46] In the Atlantic League of professional baseball, athletes who specialized early reported significantly more serious injuries (number of serious injuries [mean ± SD], 0.54 ± 0.838) during their professional baseball career than those who did not (number of serious injuries, 0.23 ± 0.425) ($P = .044$).[52] In addition, athletes in MLB from 2008 to 2016 who competed in single sports in high school had a significantly higher prevalence of upper extremity injuries compared with athletes who competed in multiple sports in high school (136 [63%] vs 55 [50%]; $P < .009$). Single-sport pitchers also had a higher prevalence of shoulder and elbow injuries (75.4% vs 56.3%, $P = .008$) and were more likely to have recurrent elbow injuries (33% vs 17% recurrence, $P = .002$) compared with multisport pitchers.[14] In a similar study of MLB athletes, players from the United States were more likely to report sustaining an injury that they attributed to specializing in 1 sport (27.7% vs 20.6%, respectively; $P < .05$) compared with those from Latin/South America.[12] Last, in a study focusing on specialization in current high school, collegiate, and professional baseball and hockey players, high school (39.9%) and collegiate athletes (42.1%) recalled a statistically greater incidence of sport-related injury than current professional athletes (25.4%) ($P < .001$).[11] In contrast to these data, in a study of first-round NFL draft picks from 2009 to 2017, there were no significant differences in games missed due to injury or total games played between multisport or single-sport athletes.[50]

In terms of individual sports, a survey of elite weightlifters found a statistically significant difference in the occurrence of injury before age 21 years between weightlifters who specialized at the youth level compared with those who did not specialize ($P < .0001$).[13] Similarly, a study of elite and World Championship wrestlers found that those who specialized before age 12 years sustained significantly more major injuries (mean, 1.14 ± 1.40) before college than those who specialized after.[36] However, in the period after college, there was no statistically significant difference in the mean number of major injuries sustained between those who specialized early and those who specialized later.[36]

Career Longevity

Career longevity of elite, Olympic, and professional athletes was discussed explicitly in 9 studies.[**] An evaluation of NBA players found that a greater percentage of the athletes who played multiple sports in their youth were active in the league at time of data acquisition, indicating increased longevity in the NBA.[46] In elite marathon runners, the mean age at career end was significantly younger in the African group who specialized younger than in the non-African group who specialized later in their career.[40]

Other articles in team sports found no difference in career longevity or career success in those athletes who specialized and those who did not. A survey comparing high school multisport versus single-sport participation in NFL players found no difference in career longevity in the league.[50] In a survey of MLS athletes, the age at specialization was not significantly different based on years in the MLS,[31] and in a study involving MLB players, there was no difference in the mean number of seasons played in the major league or minor league between athletes who specialized early and those who had not.[14]

Data were variable in individual sports. A longitudinal study of middle- and long-distance track runners at both

**References 9, 14, 26, 31, 40, 42, 46, 48, 50.

TABLE 1
Studies by Sport on the Effects of Specialization in High-Level Athletes[a]

Sport	Performance	Injury Risk	Career Success/Longevity
Baseball	Improved performance with later specialization: Confino[14]	Reduced injury risk with later specialization: Wilhelm,[52] Confino,[14] Buckley,[12] Buckley[11]	No association: Confino[14]
CGS	Improved performance with later specialization: Moesch[37]	—	—
Hockey	Improved performance with later specialization: Black[6]	—	—
Football	—	Reduced injury risk with later specialization: Steinl[50]	No association: Steinl[50]
Basketball	Improved performance with later specialization: Confino,[14] Rugg[46]	Reduced injury risk with later specialization: Rugg [46]	Increased career longevity with later specialization: Rugg[46]
Multisport	Improved performance with later specialization: Güllich[23]	—	—
Soccer	Improved performance with earlier specialization: Knapik[31]	—	No association: Knapik[31]
Marathon running	Improved performance with earlier specialization: Noble[40]	—	Increased career longevity with early specialization: Noble[40]
Track and field	Improved performance with later specialization: Boccia[9]	—	Increased career longevity with later specialization: Boccia,[9] Huxley[26] No association: Pizzuto[42]
Weightlifting	—	Reduced injury risk with later specialization: Bush[13]	—
Wrestling	—	Reduced injury risk with later specialization: McDonald[36]	—
Cycling	—	—	No association: Schumacher[48]

[a]CGS, centimeters, grams, or seconds sports.Dashes indicate data not reported.

the Junior and Senior World Championships found no association between age of specialization and playing professionally.[42] In sprinters in the junior and senior championships, those who competed only at the junior level reached their personal peak performance earlier, making their first and last appearance in the IAAF database earlier than those who appeared only in the senior championships.[9] Further, those athletes who appeared only in the senior subgroup made their first appearance in the IAAF database later and reached personal peak performance later than the U18 and senior subgroup, altogether having a longer career.[9] In a study of elite youth and senior Australian track and field athletes, 24 athletes (32.8%) participated in at least 1 junior international competition; first competed at a senior international competition in their early to mid-20s; and were, on average, 2 years older at their first Olympics and World Championships.[26] The retiring age of participants was approximately 32 years of age.[26] In elite cyclists, there was no difference in career lengths between those who competed youth versus senior championships.[48]

Table 1 provides a summary of the available data on the effects of sports specialization in high-level athletes by sport.

DISCUSSION

The purpose of this review was to summarize and aggregate data on sports specialization pertaining to professional, elite, and Olympic athletes. We aimed to summarize published motivations for specialization and the effects on injury, performance, and career success. Most available data in the 29 articles included were based on surveys but do provide broad insights into the long-term effects of sports specialization on athletes at the highest levels. All 8 articles that commented on injury risk demonstrated reduction in injury risk with later specialization. Performance benefits were apparent with later specialization in 7 of the 9 articles that discussed this metric. There were less definitive results on career longevity, with 5 of 9 articles finding no association between career longevity and sports specialization. Altogether, our results suggest delayed sports specialization or youth multisport participation was consistently associated with reduced injury risk and mostly associated with performance benefit.

Much of the prior research on youth sports and parental perceptions of sports specialization suggests that parents of youth athletes believe early specialization is the only route to higher-level play (ie, professional or Olympic) and collegiate scholarships and that this parental pressure plays a large role in a child's or young adult's decision to specialize.[29,35,38,39] Parents may believe that specialization leads to greater success than it does injury and thus remain optimistic for their child's athletic success even with more realistic interpretations of the number of collegiate scholarships available.[43] It is unclear where these beliefs stem from, though they may derive from anecdotes of

successful athletes training for hours a day in their sport. However, results of this review suggest that while parental influence on sports specialization is one of the most significant factors in decision to specialize, the large majority of elite, professional, and Olympic athletes, regardless of sport, self-choose to specialize.[12,13,18,26,31,36] Not only was self-motivation the most significant reason for specialization, but also nearly the majority of all athletes in the studies felt early specialization was not critical to success. Rather most athletes felt that participating in other sports contributed positively to their athletic success.[6,7,12,13,44] This perception of benefit and growth from multisport participation was consistent among athletes in several team sports.[7,13,44]

We found that specialization's benefits also varied by sport. In the MLS and marathon running, there were noted to be benefits from specialization. In the MLS, as previously noted, attainment of scholarship was more likely in those who specialized, and marathon runners, specifically those from Africa, had better performance by specializing earlier in their careers.[31,40] These data altogether suggest that, in sports like long-distance running, early specialization may be beneficial from a performance standpoint. However, in team sports, such as baseball and basketball, the data do not seem to demonstrate any benefit. It is unclear why most team sports have success with later specialization, though it may be related to a broader variety of movement-pattern demands in those sports.

The published literature supports the observation or position that early sports specialization is consistently associated with increased injury risk.[12,13,36,46,50,52] This injury risk was seen in both team sports and individual sports. In both the NBA and the NFL, athletes who participated in multiple sports in high school suffered significantly fewer injuries than those who played only 1 sport.[46,50] Furthermore, in both MLB and the Atlantic League, athletes who specialized at younger ages had more serious and a higher prevalence of injuries than those who specialized later.[12,52] Similar results were found for elite wresters and weightlifters.[13,36] This increased injury risk is similar to that seen even at nonprofessional stages such as in youth sports, high school sports, or college athletics. Despite the increased injury risks, sports specialization remains on the rise, with many aspiring to elite levels of performnace.[5,20] In addition to physical injuries, mental health risks including social isolation and burnout are major considerations in youth sports specialization.[27,38]

Ultimately, those who specialize early may or may not have different career longevity depending on the type of sport and its relation to age at career peak. Previous research found that athletes in gymnastics, tennis, swimming and diving, and soccer were significantly more likely to specialize early, whereas football and baseball athletes were more likely to specialize late ($P < .05$ for all groups).[47] Sports like gymnastics have a far younger age at optimal performance due to the physical demands and mobility necessary for many of the skills; therefore, later specialization may be detrimental to success. While there may be variation by sport, data are conflicting in fields like running and endurance sports, with some demonstrating benefit to career longevity and some demonstrating no long-term differences.[9,26,40] In other team sports, such as basketball, there are data to suggest later specialization increases career longeitivity.[46] However, a majority of the articles discussing longevity found no correlation between career longevity and early sports specialization.[14,26,42]

Additional questions that warrant further investigation are the aspects of nature versus nurture in developing elite athletes and whether cultural or socioeconomic differences play a role. It is difficult to determine whether athletes who play multiple sports at young ages are inherently more athletic and likely to have elite success, or if playing multiple sports is what allows for the enhanced athleticism. It is possible that in contact sports, such as football and hockey, players who specialize early sustain more injuries from contact, leading to the increased injury rates with youth sports specialization.[6,50] Georgiades et al[17] suggested that high performance athletes have an innate inability from which they are built.

Specializing in sport also relies more and more on financial support. Youth sports is a multibillion-dollar industry in the United States that is projected to continue expanding and, correspondingly, costs for families striving to have their children compete in increasingly competitive club sports are rising.[21,54] Data suggest that those with higher socioeconomic status have greater rates of sports specialization associated with higher rates of injury.[28]

Fewer data delve into the influence of culture. The included study by Noble and Chapman[40] evaluating specialization in elite marathoners found that African marathoners specialized, had higher levels of performance, and ultimately retired at younger ages than non-African marathoners. Similarly, internationally born athletes in the MLS specialized at younger ages than US-born athletes.[31] More studies are needed on evaluating cultural differences in age at specialization after controlling for sport, as well as on whether cultural differences account for variations in performance, injury, and career success.

Limitations

Several limitations exist, many of which are inherent to the systematic review process. Our systematic review compiled data that were largely retrospective or survey-based evidence; therefore, data analyses were limited to what was compiled in those studies. Furthermore, the studies included all had varied patient/athlete populations, outcomes, and study designs, making it difficult to aggregate specific types of data, so only qualitative trends such as benefits or detriments in the objectives were noted. Many of these studies relied on surveys for data collection, which are inherent to multiple forms of bias. The outcomes analyzed in this article were selected by the authors and are not comprehensive. Grouping of sports into team sports and individual sports may not be appropriate as specific sports and manners of specialization may not be comparable. Despite these limitations, we believe that our review provides important information regarding performance, career length, and injury in professional athletes in various sports.

CONCLUSION

Although current data on sports specialization in elite, professional, and Olympic athletes are mostly retrospective and survey-based evidence, most sports demonstrate better performance after youth multisport engagement, and youth sports specialization was linked with increased injury risk in athletes at the highest levels of competition. More longitudinal data on the consequences of early sports specialization in high-level athletes and data delineating outcomes by type of sport are needed.

REFERENCES

1. Allahabadi S, Calthorpe L, Pandya N. Financial and medical burdens of youth sports specialization: survey of pediatric sports patients. *J Sports Med Phys Fitness*. 2022;62(5):716-721. doi:10.23736/S0022-4707.21.12304-7
2. Barreiros A, Côté J, Fonseca AM. From early to adult sport success: analysing athletes' progression in national squads. *Eur J Sport Sci*. 2014;14(suppl 1):S178-S182. doi:10.1080/17461391.2012.671368
3. Bell DR, DiStefano L, Pandya NK, McGuine TA. The public health consequences of sport specialization. *J Athl Train*. 2019;54(10):1013-1020. doi:10.4085/1062-6050-521-18
4. Bell DR, Post EG, Trigsted SM, Hetzel S, McGuine TA, Brooks MA. Prevalence of sport specialization in high school athletics: a 1-year observational study. *Am J Sports Med*. 2016;44(6):1469-1474. doi:10.1177/0363546516629943
5. Bergeron MF, Mountjoy M, Armstrong N, et al. International Olympic Committee consensus statement on youth athletic development. *Br J Sports Med*. 2015;49(13):843-851. doi:10.1136/bjsports-2015-094962
6. Black S, Black K, Dhawan A, Onks C, Seidenberg P, Silvis M. Pediatric sports specialization in elite ice hockey players. *Sports Health*. 2019;11(1):64-68.
7. Bloom DA, Wolfert A, Whitney D, Gonzalez-Lomas G, Carter C. Characterizing sport specialization patterns in professional women's ice hockey players. *Bull Hosp Jt Dis (2013)*. 2021;79(2):93-97.
8. Boccia G, Brustio PR, Moisè P, et al. Elite national athletes reach their peak performance later than non-elite in sprints and throwing events. *J Sci Med Sport*. 2019;22(3):342-347. doi:10.1016/j.jsams.2018.08.011
9. Boccia G, Cardinale M, Brustio PR. World-class sprinters' careers: early success does not guarantee success at adult age. *Int J Sports Physiol Perform*. 2021;16:367-374. doi:10.1123/IJSPP.2020-0090
10. Brenner JS, LaBella CR, Brooks MA, et al. Sports specialization and intensive training in young athletes. *Pediatrics*. 2016;138(3):e20162148. doi:10.1542/peds.2016-2148
11. Buckley PS, Bishop M, Kane P, et al. Early single-sport specialization a survey of 3090 high school, collegiate, and professional athletes. *Orthop J Sports Med*. 2017;5(7):2325967117703944. doi:10.1177/2325967117703944
12. Buckley PS, Ciccotti MC, Bishop M, et al. Youth single-sport specialization in professional baseball players. *Orthop J Sports Med*. 2020;8(3):2325967120907875. doi:10.1177/2325967120907875
13. Bush CM, Wilhelm AJ, Lavallee ME, Deitch JR. Early sport specialization in elite weightlifters: weightlifting injury occurrence and relevant opinions. *J Strength Cond Res*. 2021;35(11):3260-3264. doi:10.1519/jsc.0000000000003239
14. Confino J, Irvine JN, O'Connor M, Ahmad CS, Lynch TS. Early sports specialization is associated with upper extremity injuries in throwers and fewer games played in Major League Baseball. *Orthop J Sports Med*. 2019;7(7):2325967119861101. doi:10.1177/2325967119861101
15. Difiori JP, Benjamin HJ, Brenner JS, et al. Overuse injuries and burnout in youth sports: a position statement from the American Medical Society for Sports Medicine. *Br J Sports Med*. 2014;48(4):287-288. doi:10.1136/bjsports-2013-093299
16. Feeley BT, Agel J, LaPrade RF. When is it too early for single sport specialization? *Am J Sports Med*. 2016;44(1):234-241. doi:10.1177/0363546515576899
17. Georgiades E, Klissouras V, Baulch J, Wang G, Pitsiladis Y. Why nature prevails over nurture in the making of the elite athlete. *BMC Genomics*. 2017;18(suppl 8):835. doi:10.1186/s12864-017-4190-8
18. Ginsburg RD, Danforth N, Kamin H, et al. Patterns of specialization in professional baseball players. *J Clin Sport Psychol*. 2014;8(3):261-275. doi:10.1123/jcsp.2014-0032
19. Gojanovic B. Sports-specialized intensive training and the risk of injury in young athletes. *Archaologie der Schweiz*. 2015;38(3):54-55.
20. Gould D. The professionalization of youth sports: it's time to act! *Clin J Sport Med*. 2009;19(2):81-82. doi:10.1097/JSM.0b013e31819edaff
21. Gregory S. How kids' sports became a $15 billion industry. *Time Magazine*. Accessed November 20, 2021. https://time.com/magazine/us/4913681/september-4th-2017-vol-190-no-9-u-s/
22. Güllich A. Many roads lead to Rome–-developmental paths to Olympic gold in men's field hockey. *Eur J Sport Sci*. 2014;14(8):763-771. doi:10.1080/17461391.2014.905983
23. Güllich A, Emrich E. Considering long-term sustainability in the development of world class success. *Eur J Sport Sci*. 2014;14(suppl 1):37-41. doi:10.1080/17461391.2012.706320
24. Hollings S, Hume P. Is success at the world junior athletics championships a prerequisite for success at world senior championships or Olympic Games? Prospective and retrospective analyses. *New Stud Athl*. 2010;25(1):65-77.
25. Hollings SC, Hume P. Progression of New Zealand and Australian World Junior Championship competitors to senior representation. 2011;26(3/4):127-135.
26. Huxley DJ, O'Connor D, Larkin P. The pathway to the top: key factors and influences in the development of Australian Olympic and World Championship Track and Field athletes. *Int J Sports Sci Coaching*. 2017;12(2):264-275. doi:10.1177/1747954117694738
27. Jayanthi N, Pinkham C, Dugas L, Patrick B, LaBella C. Sports specialization in young athletes: evidence-based recommendations. *Sports Health*. 2013;5(3):251-257. doi:10.1177/1941738112464626
28. Jayanthi NA, Holt DB, LaBella CR, Dugas LR. Socioeconomic factors for sports specialization and injury in youth athletes. *Sports Health*. 2018;10(4):303-310. doi:10.1177/1941738118778510
29. Jayanthi NA, Labella CR, Fischer D, Pasulka J, Dugas LR. Sports-specialized intensive training and the risk of injury in young athletes: a clinical case-control study. *Am J Sports Med*. 2015;43(4):794-801. doi:10.1177/0363546514567298
30. Kearney PE, Hayes PR. Excelling at youth level in competitive track and field athletics is not a prerequisite for later success. *J Sports Sci*. 2018;36(21):2502-2509. doi:10.1080/02640414.2018.1465724
31. Knapik DM, Rizzone KH, Voos JE. Timing and reasons behind single-sport specialization in soccer: a survey of 64 major league soccer athletes. *Sports Health*. 2020;12(4):355-360. doi:10.1177/1941738120911373
32. LaPrade RF, Agel J, Baker J, et al. AOSSM early sport specialization consensus statement. *Orthop J Sports Med*. 2016;4(4):2325967116644241. doi:10.1177/2325967116644241
33. Leite N, Baker J, Sampaio J. Paths to expertise in Portuguese national team athletes. *J Sports Sci Med*. 2009;8(4):560-566.
34. Lidor R, Lavyan NZ. A retrospective picture of early sport experiences among elite and near-elite Israeli athletes: developmental and psychological perspectives. *Int J Sport Psychol*. 2002;33(3):269-289.
35. Malina RM. Early sport specialization. *Curr Sports Med Rep*. 2010;9(6):364-371. doi:10.1249/jsr.0b013e3181fe3166
36. McDonald C, Deitch J, Bush C. Early sports specialization in elite wrestlers. *Sports Health*. 2019;11(5):397-401. doi:10.1177/1941738119835180
37. Moesch K, Elbe AM, Hauge MLT, Wikman JM. Late specialization: the key to success in centimeters, grams, or seconds (CGS) sports. *Scand J Med Sci Sports*. 2011;21(6):282-290. doi:10.1111/j.1600-0838.2010.01280.x
38. Mostafavifar AM, Best TM, Myer GD. Early sport specialisation, does it lead to long-term problems? *Br J Sports Med*. 2013;47(17):1060-1061. doi:10.1136/bjsports-2012-092005

39. Myer GD, Jayanthi N, DiFiori JP, et al. Sports specialization, part II: alternative solutions to early sport specialization in youth athletes. *Sports Health*. 2016;8(1):65-73. doi:10.1177/1941738115614811
40. Noble TJ, Chapman RF. Marathon Specialization in elites: a head start for Africans. *Int J Sports Physiol Perform*. 2018;13(1):102-106. doi: 10.1123/ijspp.2017-0069
41. Padaki AS, Ahmad CS, Hodgins JL, Kovacevic D, Lynch TS, Popkin CA. Quantifying parental influence on youth athlete specialization: a survey of athletes' parents. *Orthop J Sports Med*. 2017;5(9): 2325967117729147. doi:10.1177/2325967117729147
42. Pizzuto F, Bonato M, Vernillo G, La Torre A, Piacentini MF. Are the world junior championship finalists for middle- and long- distance events currently competing at international level? *Int J Sports Physiol Perform*. 2017;12(3):316-321. doi:10.1123/ijspp.2015-0717
43. Post EG, Rosenthal MD, Rauh MJ. Attitudes and beliefs towards sport specialization, college scholarships, and financial investment among high school baseball parents. *Sports (Basel)*. 2019;7(12):247. doi: 10.3390/sports7120247
44. Riewald S (ed)Snyder C. The path to excellence: a view on the athletic development of U.S. Olympians who competed from 2000–2012. Initial Report of the Talent Identification and Development Questionnaire to U.S. Olympians. USOC Sport Performance and Coaching Education Divisions; 2014.
45. Ross KA, Fried JW, Bloom DA, Gonzalez-Lomas G. The effect of specialization and level of competition on injury in elite male ice hockey players. *Phys Sportsmed*. 2022;50(4):295-300. doi:10.1080/ 00913847.2021.1916786
46. Rugg C, Kadoor A, Feeley BT, Pandya NK. The effects of playing multiple high school sports on National Basketball Association players' propensity for injury and athletic performance. *Am J Sports Med*. 2018;46(2):402-408. doi:10.1177/0363546517738736
47. Rugg CM, Coughlan MJ, Li JN, Hame SL, Feeley BT. Early sport specialization among former National Collegiate Athletic Association athletes: trends, scholarship attainment, injury, and attrition. *Am J Sports Med*. 2021;49(4):1049-1058. doi:10.1177/ 0363546520988727
48. Schumacher YO, Mroz R, Mueller P, Schmid A, Ruecker G. Success in elite cycling: a prospective and retrospective analysis of race results. *J Sports Sci*. 2006;24(11):1149-1156. doi:10.1080/ 02640410500457299
49. Slim K, Nini E, Forestier D, Kwiatkowski F, Panis Y, Chipponi J. Methodological index for non-randomized studies (MINORS): development and validation of a new instrument. *ANZ J Surg*. 2003;73(9):712-716. doi:10.1046/j.1445-2197.2003.02748.x
50. Steinl GK, Padaki AS, Irvine JN, Popkin CA, Ahmad CS, Lynch TS. The prevalence of high school multi-sport participation in elite National Football League athletes. *Phys Sportsmed*. 2021;49(4): 476-479. doi:10.1080/00913847.2020.1856632
51. Weisenberger L. Early sports specialization leads to injuries. *Am Orthop Soc Sports Med*. 2019. Accessed November 20, 2021. https://www.sportsmed.org/aossmimis/Members/About/Press_Releases/2019-Specialty-Day/Early-Sports-Specialization-and-Increased-Injury-Rates.aspx?WebsiteKey=4bcab047-256c-48fa-9eac-3641a0eb87c7.
52. Wilhelm A, Choi C, Deitch J. Early sport specialization: effectiveness and risk of injury in professional baseball players. *Orthop J Sports Med*. 2017;5(9):2325967117728922. doi:10.1177/2325967117728922
53. Wu M, Fallon R, Heyworth BE. Overuse injuries in the pediatric population. *Sports Med Arthrosc Rev*. 2016;24(4):150-158. doi:10.1097/ JSA.0000000000000129
54. Youth sports market projected to reach $77.6 billion by 2026--comprehensive industry analysis & insights. *GlobeNewsire*. Accessed November 20, 2021. https://www.globenewswire.com/news-release/2019/12/26/1964575/0/en/Youth-Sports-Market-Projected-to-Reach-77-6-Billion-by-2026-Comprehensive-Industry-Analysis-Insights.html

APPENDIX

TABLE A1
Summary of Included Studies (N = 29)[a]

Lead Author (Year)	Years Included	Location	No. of Athletes (Sex)	Mean Athlete Age, y	Sport	Level of Play	Athlete Population
Barreiros (2014)[2]	1988-2008	Portugal	395 (both)	–	Multiple	National	Soccer, volleyball, swimming, and judo
Black (2019)[6]	–	US/Canada	44 (male)	22	Hockey	Professional	1 NHL team
Bloom (2021)[7]	–	US	54 (female)	–	Hockey	Professional	2 NWHL teams
Boccia (2019)[8]	1994-2004	Italy	5919 (both)	–	Track and field	Elite	100 m sprint, 100/110 m hurdles, discus throw, and shot put athletes in the FIDAL database
Boccia (2021)[9]	2000-2018	International	4924 (both)	–	Track and field	Elite	Sprinters
Buckley (2017)[11]	2015-2016	US/Canada	1731 (male)	23.6	Hockey, baseball	Professional	MLB (1673 athletes) and NHL (58 athletes)
Buckley (2020)[12]	2015-2016	US/Canada	1621 (male)	23.60	Baseball	Professional	MLB (26 organizations)
Bush (2021)[13]	–	US	141 (both)	27.9	Weightlifting	Elite	Top 20 weightlifters in each weight class
Confino (2019)[14]	2008-2016	US/Canada	746 (male)	–	Baseball	Professional	MLB
Ginsburg (2014)[18]	2008	US/Canada	708 (male)	22	Baseball	Professional	MLB and MiLB teams in 6 states
Güllich (2014)[22]	2012	International	54 (male)	22	Field hockey	Olympic, national, world	Olympic champions, international medalists 10 years before (2002) world or national level

(continued)

Table A1 (continued)

Lead Author (Year)	Years Included	Location	No. of Athletes (Sex)	Mean Athlete Age, y	Sport	Level of Play	Athlete Population
Güllich (2014)[23]	–	Germany	1558 (both)	–	Multiple	Olympic	German national athletes across 47 Olympic sports between 1999-2002
Hollings (2010)[24]	1986-2008	International	339 (both)	–	Multiple	Olympic, world	World senior champion, or an Olympic champion or a medalist at the 2008 Beijing Olympic Games and had competed at an IAAF World Junior Championships
Hollings (2011)[25]	1986 to 2006 (junior) or 2009 (senior)	Australia and New Zealand	536 (both)	–	Track and field	World	Junior/elite IAAF World Championships and Commonwealth Games
Huxley (2017)[26]	1986-2013	Australia	73 (both)	Range, 31-60	Track and field	Elite senior international	IAAF or Olympics, 1986-2013
Kearney (2018)[30]	2005-2015	UK	134,313 (both)	–	Track and field	National	All participants who appeared in the UK Power of 10 database in 1 of 9 events
Knapik (2020)[31]	2017	US/Canada	64 (male)	–	Soccer	Professional	MLS (2 organizations)
Leite (2009)[33]	–	Portugal	112 (male)	–	Multiple	National	Portuguese male national teams from 2006-2007 world championship
Lidor (2002)[34]	–	Israel	141 (both)	27.3 (elite), 28 (near-elite)	Multiple	Elite and near-elite	Israeli elite athletes who represented country in Olympics or world championships; near-elite athletes who competed at the highest national level
McDonald (2019)[36]	–	US	143 (both)	–	Wrestling	Elite and world	Wrestlers in world championship and NCAA
Moesch (2011)[37]	2009	Denmark	243 (both)	Range, 13-51	CGS sports	Elite	CGS elite and near-elite athletes
Noble (2018)[40]	2001-2015	International	180 (both)	–	Marathon running	Elite	Top 90 African marathon runners
Pizzuto (2017)[42]	2002-2015	International	368 (both)	–	Track and field	World	Eight male and the 8 female finalists of 5 WJC middle and long-distance events (800 m, 1500 m, 3000 m, 5000 m and 10,000 m) in 2002, 2004, 2006, 2008, 2010, 2012
Riewald (2014)[44]	–	US	299 (both)	–	Multiple	Olympic	US winter and summer Olympic athletes, 2000-2012
Ross (2022)[45]	–	US/Canada	35 (male)	27	Hockey	Professional	NHL and minor league organizations
Rugg (2018)[46]	2008-2015	US/Canada	237 (male)	21	Basketball	Professional	First-round NBA draft picks, 2008-2015
Schumacher (2006)[48]	–	International	8004 (both)	–	Cycling	World	Junior and senior elite competition in grand tours and world championships
Steinl (2021)[50]	2008-2017	US	318 (male)	22.0 (multisport), 22.3 (single sport)	Football	Professional	First-round NFL draft picks, 2008-2017
Wilhelm (2017)[52]	2016	US	102 (male)	Range, 22-40	Baseball	Professional	Atlantic League players

[a]Dashes indicate data not reported. CGS, centimeters, grams, or seconds sports; FIDAL, Italian Athletics Federation; IAAF, International Association of Athletics Federations (World Athletics); MLS, Major League Soccer; MiLB, Minor League Baseball; MLB, Major League Baseball; NBA, National Basketball Association; NCAA, National Collegiate Athletic Association; NFL, National Football League; NHL, National Hockey League; NWHL, National Women's Hockey League; WJC, World Junior Championships.

TABLE A2
Study Design and MINORS Score of the Included Studies[a]

Lead Author (Year)	Study Design	MINORS Score
Barreiros (2014)[2]	Retrospective cohort	5
Black (2019)[6]	Survey	7
Bloom (2021)[7]	Survey	7
Boccia (2019)[8]	Retrospective case series	7
Boccia (2021)[9]	Retrospective case series	7
Buckley (2017)[11]	Survey	7
Buckley (2020)[12]	Survey	7
Bush (2021)[13]	Survey	7
Confino (2019)[14]	Descriptive epidemiology online search	7
Ginsburg (2014)[18]	Survey	7
Güllich (2014)[22]	Survey	7
Güllich (2014)[23]	Survey	8
Hollings (2010)[24]	Retrospective case series	12
Hollings (2011)[25]	Retrospective cohort	9
Huxley (2017)[26]	Survey	7
Kearney (2018)[30]	Retrospective case series	10
Knapik (2020)[31]	Survey	7
Leite (2009)[33]	Survey	7
Lidor (2002)[34]	Survey	7
McDonald (2019)[36]	Survey	7
Moesch (2011)[37]	Survey	7
Noble (2018)[40]	Retrospective cohort	13
Pizzuto (2017)[42]	Retrospective case series	8
Riewald (2014)[44]	Survey	7
Ross (2022)[45]	Survey	7
Rugg (2018)[46]	Descriptive epidemiology online search	8
Schumacher (2006)[48]	Retrospective cohort	9
Steinl (2021)[50]	Descriptive epidemiology online search	10
Wilhelm (2017)[52]	Survey	7

[a]MINORS, Methodological Index for Nonrandomized Studies.