UNIVERSITY OF CALIFORNIA, IRVINE

An Intervention for Improving Diet Quality Among College Students Through Small and Simple Diet-Related Behaviors

DISSERTATION

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DOCTOR OF PHILOSOPHY

in Public Health

by

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DEDICATION

To

my God, my wife and children, my students, and everyone who reached down to lift me up

Nevertheless, Jacob, my firstborn in the wilderness, thou knowest the greatness of God; and he shall consecrate thine afflictions for thy gain.

(2 Nephi 2:2)

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ABSTRACT OF THE DISSERTATION

An Intervention for Improving Diet Quality Among College Students Through Small and Simple Diet-Related Behaviors

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Doctor of Philosophy in Public Health

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Assistant Professor Karen L. Lindsay, Chair

Dietary patterns and food choices play a significant role in the health of communities and individuals. Evidence suggests that while college students do not experience a high prevalence of chronic illness, their diet quality is extraordinarily poor. This dissertation performed a systematic review and conducted a randomized controlled trial to evaluate the impact and effect of simple and personalized diet-related behavioral interventions on diet quality among young adults, specifically those who are attending college.

First, a systematic review was conducted to identify and synthesize the findings of previously published studies among young adults, aged 18-35 years, which tested the effects of easy-to-learn interventions when compared to passive or alternative treatments on overall diet quality or constituents of diet quality. Next, cross-sectional analysis of baseline data from a behavioral intervention study for improving diet quality in college students was conducted with the goal of identifying associations between perceived stress and diet quality, and the moderating

role of food security status. Finally, a randomized controlled trial investigated the effects of a simple and individually modifiable intervention on the diet quality of college students. Participants in the control group were asked to read and consider the principles of the dietary guidelines for Americans, and participants in the experimental group selected two dietary change statements which were printed into keychain tags and carried on their person to provide a consistent reminder of their desired dietary improvement.

Five of the nine studies included in the systematic review reported significant improvement to the selected dietary outcome between groups. Four of these studies used an implementation intentions approach that had participants write out a simple dietary behavior directive and carry it with them for the study duration, and three reported significant differences between groups. The average Cohen's d effect size for all included studies was 0.26. Next, results from the cross-sectional analysis reported no significant associations between perceived stress and HEI-2020 or any component of diet quality, however, there were significant interactive effects for food security and perceived stress on total vegetable and total protein component scores. Lastly, results of the trial intervention reported no significant differences within or between the control and experimental groups at any time point for HEI-2020 total or component scores, with the exception an increase in total vegetable score from baseline to week 4 in the control group only. Despite the non-significant findings, the majority of the participants reported satisfaction with the intervention's ease and utility.

Prior evidence suggests that small-scale and individualized efforts can play a role in promoting healthy behaviors in college students. Additional efforts to improve diet quality should consider both the personal and structural circumstances that students encounter during their time in academia.

INTRODUCTION

Human dietary patterns – the discernible organization of a person's dietary choices – are varied, complex, and integrally tied to human health. Dietary patterns will differ among populations, but also change within those populations as new life events or circumstances unfold. Nutrition research overwhelmingly indicates that dietary patterns and food choices play a significant role in the health of communities and individuals, manifest through alternations in chronic disease risk, improvements or declines in disease management, and even within acute metabolic fluctuations. Therefore, public health officials seek to assess and promote optimal dietary patterns among all populations within the United States, based on current dietary recommendations.

The Dietary Guidelines for Americans (DGAs) have long served as the cornerstone to federal nutrition policy and are updated every five years to reflect recent empirical findings on optimal dietary patterns that lower risk of chronic illness.[1] There are numerous methods and scales validated for measuring dietary behaviors, but one of the most robust is the Healthy Eating Index (HEI), also updated every five years to assesses how well a dietary pattern aligns with the DGAs.[2] The average HEI-2020 for all Americans (scored 0-100) is currently 58, far below the recommended score of at least 80. Americans of all ages and demographics have a collective need to improve their dietary habits, however, young adults, typically defined by the age range of 18 to 35, have particularly low scores.[2,3] Furthermore, many young adults will attend college to pursue advanced studies and bear new responsibilities while learning to independently manage their life and health.

Many young adults who attend college need to improve the quality of their diet, and it is currently unclear how best to accomplish this task. Therefore, the purpose of this dissertation is to assess previous efforts to improve the diet quality of young adults through easily learned interventions, explore additional factors that may predict or associate with their diet quality, and determine whether or not a simple and personalized intervention can effectively improve the diet quality of full-time college students. This introductory chapter will discuss in greater detail the role that diet plays within human health and disease outcomes, the current diet quality of college students, previous efforts to improve their diet quality through simple or structural interventions, and frameworks that justify the benefit of simple dietary interventions.

Disease Risk from Poor Dietary Intake

Dietary intake and chronic disease are inseparably connected, with significant and robust evidence suggesting that a high-quality diet can reduce the risk or improve the management of chronic diseases. At the same time, low-quality diets augment the risk for or worsen outcomes for those who already have chronic disease.

All-Cause Mortality

All-cause mortality is a broad and impactful measure of health outcomes, and numerous studies have explored its associations with diet quality. Among findings from a meta-analysis of cohort and cross-sectional studies, comprised of 922,199 adults, high adherence to diet quality as measured by HEI was significantly associated with a 23% reduced risk of all-cause mortality (Relative Risk [RR] = 0.77, 95% CI = 0.76–0.78), with findings still significant after sensitivity analysis.[4]

From the Atherosclerosis Risk in Communities (ARIC) study that collected 25 years of data, the highest quintile of diet quality reported a median HEI score of 81, with an 18% reduced risk for all-cause mortality after adjusting for demographic and lifestyle covariates, compared to the reference group (Hazard Ratio [HR] = 0.82; 95% CI = 0.75–0.89; *P*-trend < 0.001). The study reported similar all-cause mortality findings for alternative dietary measurements and patterns, such as the alternative HEI (AHEI), the Dietary Approaches to Stop Hypertension (DASH), and the alternate Mediterranean diet (aMed). Even within the quintile right above the reference group, there was a 10% reduction in all-cause mortality (HR = 0.90; 95% CI = 0.83–0.97; *P*-trend < 0.001).[5]

As a final example, the Southern Community Cohort Study, a prospective cohort comprised of 84,735 adults aged 40 to 79, reported a 20% difference in all-cause mortality risk between the lowest and highest quintiles for diet quality scores (HR = 0.80; 95% CI = 0.73–0.86; *P*-trend < 0.05). The significance of these findings remained regardless of sex, race, or income.[6]

Cardiovascular Disease

Cardiovascular disease (CVD) is the leading cause of death in the United States, resulting in nearly a quarter of all deaths annually and demonstrating strong associations to diet quality.[7] Similar to findings of all-cause mortality, robust meta-analyses and cohort trials reported reductions in CVD risk when comparing the outcomes among the lowest and highest diet quality groups. Yu et al reported a 19% reduction (HR=0.81; 95% CI = 0.70–0.94), Onvani et al reported a 23% reduction (RR = 0.77; 95% CI = 0.74–0.80), and Hu et al reported the greatest reduction at 32% (HR = 0.68; 95% CI = 0.58–0.80; P-trend < 0.001).[4–6] These risk reductions are likely an effect of overall diet rather than inclusion of a single group or nutrient.[8]

Cancer

Cancer is the second leading cause of death in the United States, presenting in many different forms and significantly associated with dietary patterns.[7] Based on data from two ongoing cohort studies that included 132,606 participants, the highest quartile of diet quality (measured by AHEI), observed a 16% reduction in risk for colorectal cancer mortality (HR = 0.84; 95% CI = 0.73-0.96; *P*-trend = 0.01).[9] These findings are concurrent with earlier studies reporting significant risk reductions in various cancer types, when comparing highest and lowest diet quality scores.[6,10]

In spite of these findings, not all studies assessing cancer outcomes have found significant benefit from improved diet. Specifically, HR for epithelial ovarian cancer cases comparing the highest with the lowest quintile HEI score was 0.85 (95% CI = 0.65-1.12; *P*-trend = 0.57). Using the AHEI, a similar diet score metric, the HR was 1.03 (95% CI = 0.80-1.34; *P*-trend = 0.77), also failing to achieve significance.

Health Improvement through Dietary Pattern Compliance

As outlined above, numerous studies have investigated large populations with poor adherence to dietary guidelines, and reported increased risk for various illnesses and conditions. As a contrast, there is abundant literature for interventions that successfully prompted dietary pattern compliance, and reported positive outcomes among study participants.

The DASH diet was first formally described and published in 1997, in a study of 459 adults with varying levels of blood pressure, assigned to one of three diets for eight weeks.[11] The three diets included, 1) a control diet more reflective of the standard American intake at the time, 2) a diet rich in fruits and vegetables, and 3) a “combination” diet (later called the DASH diet) rich in fruit and vegetables, while low in total and saturated fat and in sodium intake. Among all subjects, the DASH diet, along with the fruit and vegetable rich diet, significantly reduced blood pressure independent of weight loss, when compared to the control diet. When stratified by those who were hypertensive and non-hypertensive, the effects were even more pronounced, especially within the DASH diet group.[12]

Reductions in systolic and diastolic blood pressure have been replicated in various other groups who follow the DASH diet, whether paired with physical activity, or when there was another chronic illness present, such as diabetes.[13] In the years since, DASH-inspired interventions that elevate dietary compliance have reported favorable effects on other conditions and populations, such as weight, pregnancy, CVD, diabetes, and genetic clotting disorders among teenagers.[14–18]

The Mediterranean diet is another dietary intake pattern that improves adherence to the DGAs, and is typically comprised of high monounsaturated fat intake and daily consumption of fruits, vegetables, whole grain cereals, and legumes.[19] In the multicenter PREDIMED study conducted in Spain, 7,447 participants with high CVD risk, but no disease at enrollment, were assigned to one of two variations of this diet, or a control.[20] After a median follow-up period of 4.8 years, wherein all major cardiovascular events were tracked, intent-to-treat analysis calculated an HR of 0.69 (95% CI = 0.53-0.91) for a Mediterranean diet with extra-virgin olive oil and 0.72 (95% CI = 0.54-0.95) for a Mediterranean diet with nuts, as compared to the control diet.[21] Many additional studies prescribing a Mediterranean diet reported similar benefits in reducing risk of CVD through improvement of more immediately measurable changes, such as endothelial function, plasma glucose, triglycerides, HbA1C, blood pressure, and HDL.[22–24]

Diet quality can trigger either an elevation or reduction in the risk of chronic illness, both in long- or short-term settings. While the potential for disease risk reduction through diet is encouraging, this prompts additional questions regarding how to improve and sustain better diet quality. For many populations, including college students, struggling to sustain changes in diet may transcend simple knowledge requirements and instead derive from alternative barriers to improved dietary intake. Furthermore, certain components of dietary practice may require improvement, such as fruit and vegetable intake, while others, such as lean protein consumption, may not require improvement.

College Students and Dietary Patterns

The time period of transition from youth into adulthood – which for many in the U.S. and other developed countries marks entry into college – is pivotal for young adults to develop life-long, healthy practices. Many college students can no longer rely on previous support systems, are in process of developing a more fixed expression of identity, and find themselves carrying new responsibilities.[25–27] This represents a fortunate opportunity given how many college students collectively report dietary patterns inconsistent with recommended guidelines.[28,29]

College-aged individuals may struggle to convert general dietary counsel into actionable dietary behaviors, as evidenced by numerous reported barriers, such as cost, lack of interest, incorrect perceptions about food and diet, and negative perceptions regarding ability to make change.[30–33] The nature or extent of these barriers can potentially limit the effectiveness of a dietary intervention. Furthermore, many interventions may require additional time demands, such as enrollment in a select class or program, upon the already demanding schedules of students and thereby limit who can participate.[34,35] This prompts questions about alternative and easier approaches to modifying diet which consider the numerous factors that impact dietary choices, as well as what components of a college students' diet needs improvement.

Dietary Guideline Adherence in College Students

Evidence from studies evaluating intake practices among college students suggest suboptimal dietary patterns. In nationwide surveys of college student behaviors, 18.7% reported eating more than two servings of fruit per day, and 36% reported similar intake for vegetables.[36] Previous studies report that teenagers and young adults consume more calories per day from sugar-sweetened beverages (SSB) than any other age demographic, with average daily energy intake from all SSBs for young adults (ages 20 to 34) being 338±99 kcals/day.[37,38] Even among students pursuing health-related majors, few managed to meet dietary recommendations.[39]

Diet quality scores are consistently low for college students when using the Healthy Eating Index (HEI), a robust scale scored from 0 to 100 to measure compliance with dietary guidelines, recommending a minimum score of 80 for reduced risk of chronic illness.[40] Nationwide reporting using standardized recalls methods observed an average HEI score of 64.8±0.2 among the generalized student body.[41] Yu et al[42] reported slightly higher scores among college freshmen when compared to the national average of adults and children (60.9 vs. 58.3, $P < 0.05$). Hispanic freshman scored much lower, with an average HEI of 54.9.[42] Even among students who had recently completed an introductory nutrition course, the mean score was 68.3±18.3.[43] It is difficult to discern how diet quality among college students has changed over the previous decade, though the earliest uses of the HEI measure among college students reported similar low scores.[28]

Numerous studies report a general increase in weight among college students, usually during the first years of study. From a systematic review and meta-analysis representing 3,401 college freshmen, there was a mean weight gain of 3.86 pounds over the course of 3 to 12 months.[44] As described by Holm-Denoma and colleagues, the amount of weight gained varies significantly, but ample evidence suggests a metabolic shift towards excessive energy intake in college settings, with numerous factors contributing to the shift, such as evening snacking, increase in energy dense foods, and decrease in physical activity.[45]

Barriers and Facilitators to Dietary Compliance in College Students

Numerous studies have explored the dietary patterns, behaviors, and beliefs of college students, using both qualitative and quantitative tools. Across universities and student subpopulations, studies often report similar findings regarding challenges or facilitators to improving diet. For example, in two separate studies conducted at universities in separate nations, with distinct socioeconomic backgrounds, both study participants suggested that portion control, self-discipline, and time management could improve their diet, but noted the cost of food, challenges from social networks, and limited knowledge making it harder to eat a healthy diet.[46,47]

Qualitative studies have identified barriers to healthier diet within individual, social, and environmental realms of influence. Individually, students cite disinterest in prioritizing their health, mindless snacking, or personal failings to go and exercise. Socially, peer settings may pressure students to eat more energy-dense foods or engage in unhealthy practices. Parents may also elicit social influence on eating habits, especially if students considered them too restrictive while living at home. Environmentally, students perceive a lack of healthy choices on campus, abundant fast-food outlets, or vending machines offering cheap and energy-dense food. Living situations may limit abilities to prepare healthier meals. Lastly, the time constraints of student life (attending classes, club meetings, or student-related duties) often compete for student's time and attention.[30,31]

As a contrast, each of these realms of influence concurrently offers facilitators to healthy eating practices. Individually, developing strong beliefs, a greater value of health, and habitual, actionable behaviors were facilitators. Socially, peers who bond over health-promoting activities are perceived as facilitators, and parents of students who modeled and encouraged healthy eating habits at home improved attitudes and food intake when away from home. Environmentally, students believe that better food choices at dining services, as well as general options around campus would facilitate better eating practices.[30,31]

The picture of how to best assist college students to improve dietary intake becomes complicated given the perceived, dual nature of many factors as both barrier or facilitator. Individual actions and core beliefs, behavioral influence of peers, or the practices of parents could all either contribute to or detract from healthy dietary patterns.[30] From identifying the gaps in a college student's diet quality, to determining what factors contribute to those gaps, the goal then becomes to formulate appropriate interventions that lead to sustainable dietary behavior change.

Challenges with Implementing and Sustaining Dietary Change

A change in diet may effectively improve diet quality, or lead to weight loss, or another desirable outcome, but if ultimately rejected as part of an ongoing lifestyle, the benefits are unlikely to persist. Difficulty with maintaining new dietary patterns most commonly manifest within or after weight loss studies. Selection bias may favor recruitment of highly motivated participants for weight loss trials initially, but over time, the caloric deficit required to lose weight may drive persistent hunger, perceived restrictions may fatigue motivation, and dissatisfaction with results may ultimately cause people to relapse into previous dietary patterns, either during or after the study's conclusion.[48,49]

Generally, the more restrictive a diet, the higher the rate of attrition. Whether the route of dietary change is achieved through carbohydrate modification, fat reduction, or alteration in macronutrient intake, attrition rates generally increase the longer undesired dietary restrictions persist.[50,51]

Additional evidence for difficulty in maintaining dietary change is observed in weight recidivism, or weight regain. Even when participants lose significant weight through an intervention, maintaining the weight by maintaining the lifestyle changes becomes its own challenge. If the treatment does not endure, than neither will the effects. Whether the intended outcome is weight loss or dietary improvement, weight regain or a return to former dietary practices prior to the intervention are commonly reported.[52–54] Long-term maintenance of dietary changes or weight loss are usually dependent on a number of behaviors that drive conscious awareness of dietary practices, health status, and physical activity levels.[55]

Simple Change Approach to Dietary Change

At present, there is no one-size-fits-all approach to diet improvement given the multiplicity of goals or people who set them. Improving diet is often a balancing act that requires promoting specific foods while limiting others, with personal behavior, biology, and environments complicating how best to do this. Actions towards improvement can be small and stepwise, rather than complex and all at once. An exploratory trial demonstrated the usefulness of this approach by helping an experimental group achieve long-term significant weight loss through promotion of simple, easy to complete diet behaviors.[56] The experimental group received a leaflet with ten specific suggestions for how to modify their diet and increase metabolic outputs, such as choosing reduced fat foods at the grocery store, walking at least 10,000 steps every day, or eating meals at consistent times. The experimental group saw significant weight loss compared to the control which received no leaflet, and critically, retained significance of weight lost with intent-to-treat analysis 8 months after the study ended.

A number of other studies with simplistic interventions have found some measure of success in promoting a diet more consistent with the DGAs. Within an adolescent population, participants were asked to carry a water bottle on their person at all times, and by the study's termination, SSB intake was significantly lower compared to the control.[57] Similar reductions in SSB consumption were reported in a multi-component educational intervention which required middle school students to maintain a drink journal as a way to heighten their observation of what they drank.[58] In restaurant settings, using a smaller bowl, serving with a smaller spoon, or eating a meal with a larger fork in a restaurant setting all resulted in decreased caloric intake.[59,60] Drinking at least two cups of water 30 minutes previous to a meal decreased appetite for elderly participants, and subsequent smaller caloric intake, compared to no intervention.[61] Removing all electronic distractions when sitting down to a meal was associated with heightened alertness to hunger signals and reduced overall intake.[62] The choice of egg or oatmeal, rather than a bagel or ready to eat processed cereals at breakfast, resulted in heightened fullness and reduced snacking later in the day.[63,64] In office settings, the act of moving a candy dish to an obscure and difficult to reach location resulted in fewer candies eaten.[65]

Despite the limited generalizability of these findings, simple interventions can easily be modified, adapted, and applied to various populations, including college students. Simple interventions may help college students to counteract some of the environmental influences that impact diet. The idea that human behavior and environmental forces can bidirectionally impact one another is a principle of Social Cognitive Theory (SCT).

Social Cognitive Theory as a Framework for Interventions

SCT explains learned human behaviors through a reciprocal causation model. Behavior, personal factors, and the environment are the central components which each influence and exert effect on one another to ultimately shape behavior.[66] SCT is commonly applied to approaches in health intervention and evidence suggests that SCT-informed interventions tend to result in favorable and sustainable positive outcomes in dietary practices.[67,68] Given their reciprocal relationship, an intervention which improves individual behavior can potentially lead to modification of certain environmental factors, and vice versa.[66] Certain individual behaviors may be directed to modify environmental exposures within the control of the individual.

The central tenets of SCT functionally provide two paths for modifying dietary patterns; interventions directed at individual efforts, and interventions that are structural and modify environmental exposures through laws, policies, food access, or even physical infrastructure such as food outlets.[69]

Individual interventions that focus on behavior change can be tailored to suit unique needs and tap into intrinsic motivation by enhancing a person's autonomy, efforts, and perceived self-efficacy.[70] Environmental interventions are typically broad in reach, able to impact more participants within a similar environment, but consequential of this blanketed coverage, structural interventions do not consider individual circumstances and can have unintended effects if not crafted with precision.[71]

While SCT provides a framework for how individual efforts and environmental modifications can influence dietary behaviors, researchers should not feel limited to using one approach over another. Both approaches can work reciprocally to result in more desirable dietary behaviors. Simple interventions can prompt someone to eat more fruit, or to modify environmental cues within their control that lead to greater fruit intake. Either way, the functional effect is an improvement in dietary behaviors.

Purpose of this Dissertation

Additional research is needed to identify simple interventions which effectively improve diet quality among college students.[33] These interventions should be designed in a way that appeal to a broader student audience, and consciously consider the personal or structural constraints that exist in the college setting. Furthermore, interventions that promote long-term behavioral modification will net the greatest benefit among this population.

The aim of chapter 1 in this dissertation was to identify and synthesize the findings of previously published studies among young adults, aged 18-35 years, which tested the effects of easy-to-learn (ETL) interventions compared to passive or alternative treatments on overall diet quality or constituents of diet quality. The aim of chapter 2 was to examine the association between perceived stress and diet quality in a diverse population of college students from two major universities in southern California, as well as assess whether food security moderates the association between diet quality and perceived stress. The aim of chapter 3 was to investigate whether or not a simple and individually modifiable intervention could improve the diet quality of college students from two large university campuses. A secondary aim was to evaluate the feasibility of the intervention from the participants.

The implications of this dissertation may help college students to better navigate the complex and demanding environment of the university setting to improve the quality of their diet. By identifying gaps and factors that contribute to poor diet quality, researchers may tailor personalized interventions that respect individual circumstances and foster dietary behavior change that is lasting and serviceable to students both during and after their time at the university.

RESEARCH CHAPTER 1: Systematic Review of Easy-to-Learn Behavioral Interventions for Dietary Changes Among Young Adults

INTRODUCTION

Diet quality is an umbrella term frequently used to describe how well an individual's diet conforms to dietary recommendations.[72] Although there is no single definition for diet quality, it is generally accepted that a high-quality diet is one that promotes good health through optimal supply of foods and nutrients required for maintaining a healthy state, and avoiding or minimizing foods and nutrients that contribute to toxicity, ill-health, or a general lack of homeostasis. Population-level approaches to improving diet quality can be administratively complex, but carry a lower absolute cost per-person, whereas interventions aimed at individuals or specified subpopulations may be more feasible in certain contexts and can be used to inform appropriate population-level interventions.[73–75] Although comparatively limited in reach, the value of interventions that require minimal time to learn are worth consideration given the high prevalence of poor health behaviors and declining health status of individuals across the US, contributing to poor health outcomes and growing chronic disease.[2,76–79] Data from nationwide diet evaluation surveys show evidence of poor diet quality among all age spectrums, including young adults, an age demographic defined as those aged 18–35 years.[3] Young adults, many of whom are attending college, joining the workforce, or navigating newfound independence, report dietary patterns inconsistent with recommended dietary guidelines, putting them at increased risk for obesity and future chronic health conditions.[26,29,36,44]

Despite poor diet quality, young adults are not usually a focal point for nutrition interventions, perhaps in part because of the low reported prevalence for diet-related chronic disease, such as coronary heart disease, diabetes, and chronic kidney disease.[78–81] However, this period may represent a window of opportunity for primary prevention of diet-related chronic conditions because poor dietary practices and obesity in this phase of life can predict the onset and risk of disease in later adulthood.[82,83] Furthermore, young adulthood presents a unique opportunity to establish or amplify existing practices conducive to good health outcomes. These years represent a transitional milestone of learning to navigate independently without previous support systems, developing a more fixed identity, and showing greater interest shouldering new responsibilities.[25–27]

Dietary interventions designed for young adults vary in approach, sometimes taking the form of comprehensive health programs and classes or modifying environmental exposures, such as the presence of sugar-sweetened beverages (SSB).[84] Other interventions employed educational interventions, or made use of modern technology, such as cooking demonstration videos posted online or social media and text messaging campaigns to inundate study participants with healthy eating messages.[34] Although previous reviews suggest a measure of effectiveness, the reliability of the data is questionable given the variety of study designs, methods, targeted outcomes, and inherent limitations. Authors reported that successful interventions usually integrated visual cues into the students' lifestyles, such as messages on vending machines, or food selections available at purchase.[34]

Previous studies provide context for addressing the healthy eating barriers commonly cited by young adults. Among these are a lack of interest, poor self-perception of the ability to make a change, time management, or perceived feasibility.[32,33,35] Given the internalized nature of these barriers, behavior change theory suggests that interventions that simplify or facilitate perceived effort may be an effective strategy for improving diet quality within this population.[66]

Small-change approaches to improving diet and health typically focus on empowering individuals to make changes for the better within the prescribed circumstances. For this paper, we explored the effect of small-change approaches through easy-to-learn (ETL) interventions that would reasonably require no more than 1 hour for researchers to teach or explain to participants how to perform the intervention. By contrast, diet interventions or behavior changes that are excessively challenging, complex, and considered restrictive are prone to attrition or a return to previous behaviors.[51,85] The most commonly reported small-change approaches in the literature typically focus on weight reduction and, by extension, calorie modification.[86,87] However, calorie modification does not necessarily result in an improvement in diet quality, which is the ultimate goal for improving diet-related health outcomes. Diet quality itself is a multicomposited outcome comprising the sum of various dietary constituents. Therefore, even when an intervention aims to alter the intake of a single dietary component, such as an individual food or nutrient, this can translate to a shift in overall diet quality, provided that other aspects of the diet remain constant. The effects of small-change approaches to improve diet quality, especially among the young adult population, have not been reviewed.

The review aimed to identify and synthesize the methods and findings of previously published studies among young adults aged 18-35 years, which tested the effects of ETL interventions compared with passive or alternative treatments on their overall diet quality or constituents of diet quality. The results of this systematic review are intended to guide future intervention studies to reduce the perceived effort of or offer simplified methods to making dietary changes that ultimately drive improvement in diet quality among young adults.

METHODS

Literature Search

This systematic review was registered in PROSPERO under ID# CRD42022306007, and conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA).[88] A preliminary pilot search was conducted by a single author (DMM) to assess utility of search terms suitable for the review's inclusion and exclusion criteria. Only currently published studies were considered as part of this review, wherein all original data was de-identified, therefore, according to institutional policy no IRB approval was required. After collaboration with the other authors, results from this initial search were used to craft the following key terms connected by Boolean operators: [*Diet* OR Nutr**] AND [*"Nutrition intervention" OR Nudge OR "Dietary intervention" OR "Behavior modification" OR "Dietary change" OR "Dietary advice" OR "Simple approach" OR "Small change" OR "Habit formation" OR "Behavior change"*] AND [*"College" OR "18 years*" OR "35 years*" OR "Students" OR "young adult"*]. These terms were entered into PubMed, Academic Search Complete (EBSCO), Web of Science, ERIC, and CINAHL. Google Scholar was also searched for literature, but its search capacity is comparatively limited, not permitting use of more than 1 Boolean operator. Therefore, a search line was entered made up of key terms from the previous search engines, connected by a single Boolean operator: [*"simple dietary advice" OR "simple nutrition intervention" OR "dietary habit formation" OR "small change approach" OR "Nutritional nudges" OR "simple dietary advice"*]. We manually screened the limited results returned in Google Scholar to identify potentially eligible articles.

In addition, we performed backward searches of reference lists from articles returned by the systematic review search, to identify other potential articles not found using the original search terms. All searches were conducted between January 18th, 2022 and February 24th, 2022.

Inclusion And Exclusion Criteria

Criteria for inclusion within the review were: 1) interventional studies (either with a control group or using a single-arm, pre-post outcome assessment) that involved ETL behavior changes reasonably within the control of the participant, 2) measured at least 1 component of dietary intake as either a primary a secondary outcome, represented by the 2015 Healthy Eating Index (HEI-2015), and 3) addressed a young adult population aged 18 to 35 years. An ETL intervention refers to any reportable behavior change from the participant that required no more than 1 hour of engagement time to learn. This hour would not include time required to complete initial survey or data collection procedures, and if a study did not specify the time taken to communicate the intervention, reasonable inference was used by the authors based on available information. Furthermore, ETL interventions are not defined by the perceived ease or time to complete a behavior. An intervention may be perceived as difficult or time-consuming to perform by some individuals, but so long as communicating and teaching the intervention to the target audience is a reasonably quick process, it would qualify as an ETL intervention.

If the study population was broad and exceeded the 18 to 35 year age range, it was excluded if the mean age of participants was greater than 35 years. There was no cutoff publication date for included studies. Only English- and Spanish-language articles were considered.

Article Selection and Review Process

Selection of articles relied primarily upon 2 authors (DMM and IM) utilizing a two-pass method. This method requires authors to independently search the databases using the same key terms, within the same time frame, first tagging potentially-relevant articles according to title and abstract, followed by a second pass where full manuscripts are reviewed to evaluate eligibility based on inclusion and exclusion criteria.[89] The references from these manuscripts were also reviewed to identify additional studies that could potentially be included, which yielded an additional 16 studies for analysis based on title and abstract. Outcomes from the independent searches were compared and any disagreement that could not be resolved, whether for articles selected or qualification for inclusion, was remediated through appeal to a third author (KL) who made the final decision.

The review process involved careful analysis of the selected manuscripts by 2 authors. First, a summary table was created with general descriptive information about each study, including title, year of publication, authors, country of origin, use of theory described in the study, study design, control groups, and a brief description of the ETL intervention applied in the study. Two authors independently entered the information for the summary table by reading each study. Once completed, 1 author verified all information contained therein. This process was repeated for a second summary table that detailed information regarding the population of study, a breakdown of the participants, timeline of the intervention, diet-related outcomes of interest, Cohen's d effect size for each diet-related outcome, non-diet outcomes of interest, and a summary of the diet-related findings. Effect size is the standardized mean difference between groups of independent observations, calculated from mean differences of groups, standard deviations, and the number of group participants.[90] Cohen's d provides additional insight for interpreting the relevance of an effect between 2 groups. Typically, d=0.2 is considered a small effect size, 0.5 is medium, and 0.8 is large.[91] Given the heterogenous nature of the studies, including study outcomes, measurement method of selected outcomes, and intervention lengths, a descriptive analysis of the evidence was conducted in lieu of a meta-analysis. Relevant features, methods, and outcomes of the studies were compared and discussed in relation to previous literature.

The summary of diet-related findings reported any significant or non-significant differences in diet-related outcomes within and between groups. Information regarding stratification of study population demographics was included as reported in each study. Outcome data regarding non-diet outcomes was reported but not discussed in detail, as this was not within the purview of this review. Summaries of findings from authors were compared and reported regarding relevant conclusions and study limitations.

Quality Assessment of Included Studies

Study quality was analyzed using the Quality Criteria Checklist (QCC) for Primary Research, provided by the Academy of Nutrition and Dietetics.[92] This tool helps researchers to identify concepts that are widely accepted as elements of rigorous scientific investigation, such as clearly stated research questions, bias assessment, comparable study groups, clear definitions of outcomes, and limitations due to bias of funding. Two authors independently reviewed each study using the objective criteria set forth in the QCC, scoring as appropriate, and then meeting to discuss findings and resolve any discrepancies. A final evaluation of study quality was designated for each study, based upon the QCC. The QCC offers a list of 10 questions to assess study quality, and based upon the responses to those questions, offers 1 of 3 designations for the study’s overall quality; positive, neutral, or negative.

RESULTS

Study Selection

The initial search yielded 9,538 articles for review. During the first pass, 136 articles were retained for additional review based on title and abstract; manuscripts were read in full to determine eligibility for inclusion. Among the selected studies, a second review of the full manuscripts was performed and brief notes were made about the reason for exclusion, where applicable. Commonly cited reasons for exclusion were failing to meet the review's definition of an ETL intervention, such as an intervention outside of the control of the participant or one that required more than an hour to learn.[93,94] After review of the full manuscripts, 18 articles were retained and discussed between 2 authors. By deliberation and appeals to a third author for resolution, 9 articles were retained for final inclusion within the review, none of which were in the Spanish language. The figure presents an overview of the study search and selection process.

Description Of Included Studies

Table 1.1 describes the study design, behavior change theories employed, timeline of treatment, and details of the intervention and control for included studies. The studies spanned a 25 year time period, with the most recent study published in 2021 and the oldest in 1997.[95,96] Five studies originated in the United Kingdom, 2 from the United States, 1 from Germany, and 1 from South Korea. A randomized controlled trial (RCT) design, utilizing a pre- and post-assessment method was the most commonly utilized study design. Only 2 studies were not RCTs; Park et al[96] conducted a single-armed feasibility design, and Heatherington et al[97] employed a repeated measures analysis for 4 different scenarios. Of the 7 RCT studies, only 1 had 2 intervention groups that were compared to a control group.[98]

Five of the 9 studies discussed the use of theory in planning and executing the intervention. Two studies, both of which were conducted by the same author, made use of the theory of planned behavior (TPB).[99,100] One study made use of social cognitive theory (SCT).[101] Another looked at self-determination theory (SDT), while the final study drew from both SCT as well as SDT in planning its intervention.[98,102]

The most commonly employed intervention was an implementation intentions approach, utilized by 4 studies wherein participants were given or asked to write out a simple health behavior directive and carry it on their person as a prompt.[98–100,103] Two studies used media created by the researchers that was tailored to the target audience as a means to communicate diet and nutrition-related messages.[101,102] One study required a specific food item selected by the researchers to be consistently consumed by participants.[95] One study offered directives on the makeup of the physical environment in which a person consumed a meal.[97] The last study borrowed from tenets of time-restricted eating and had participants select and stick to a time window within which they ate all their food.[96]

Only 2 studies did not include any form of control group in their design.[96,97] Four studies utilized a passive control group, where no instructions or alternative intervention were applied beyond collection of the same data required of the experimental group.[95,98–100] The remaining 3 studies had alternative instructions or interventions provided to the control in contrast to the experimental group; 5-minute videos on sleep disorders instead of 15-minute culinary videos, implementation intentions for consuming water instead of diet beverages, and a content identical Facebook group but without the use of a smartwatch.[101–103]

The timeline for implementation of these interventions, from baseline assessment to final contact with participants, ranged from 2 weeks to 5 months.[100,101] Only 3 of the studies included a follow-up assessment after the designated end point of the intervention period, ranging from 1 week to 4 months, using the same dietary measures that were conducted at the interventions' endpoint.[95,98,101]

Table 1.2 describes the study population, outcome measures, and diet-related results for included studies. Among the 9 studies included in this review, the total number of participants was 872. The largest study had 264 participants, while the smallest had 33.[96,99] With the exception of Hetherington et al,[97] every study had more female than male participants. Considering the combined total of participants within all 9 studies, 67% (n=584) were females and 33% (n=288) were males. Only 1 study included data stratification of racial and ethnic backgrounds for study participants.[103] Aside from reporting race, sex, body mass index (BMI), and age, the only other participant demographics reported were campus living conditions and use of the dining hall in 1 study.[101] Six of the 9 studies recruited participants who were confirmed to be students in college, while the remainder reported a mean age of less than 35 years within their pool of participants. The oldest mean age of any study's population was 33 years.[99]

Three studies selected more than 1 marker of diet as outcome measures, such as whole grain intake or fruit and vegetable consumption, while the rest of the studies only assessed a single marker of diet quality.[95,96,102] The most commonly reported dietary intake marker was fruit and/or vegetables, though these were measured in a distinct method for each study.[98,100–102] In addition to fruit and vegetable intake,[98,100–102] other measures of dietary intake assessed included total and saturated fat,[95,96,99] added sugar,[95–97] total protein,[95,96] whole grains,[102] SSBs,[102,103] and macronutrients as a percentage of total energy.[96] With the exception of Ungar et al,[98] every study included secondary outcomes which went beyond the scope of dietary intake. These were highly varied within each study and included items such as program feedback, participant behavior (i.e., activity during mealtimes, physical activity), BMI, and hedonic liking.

Results Of Diet-related Outcomes

Only 3 studies did not report any significant dietary changes, neither within nor between groups.[96,101,102] Of these, 2 studies[101,102] prescribed media for communication of nutrition messages (cooking program, Facebook group) but failed to detect any significant changes in diet-related outcomes, though Clifford et al reported improvements for knowledge in fruit and vegetable recommendations as a secondary outcome. Park et al[96] had a single group complete 4 weeks of time-restricted eating, but did not observe any changes within the group when comparing intake patterns at baseline and end of study.

Five of the included studies reported some degree of dietary improvements between their intervention and control groups, while 1 study only reported a within-group difference. Armitage[99] observed significant reductions in fat intake for the experimental group, when compared to the control group. In a later study observing fruit intake, Armitage[100] again reported higher fruit intake for the experimental arm compared to the control. Between baseline and the end of the study, Ungar et al[98] noted that all 3 groups had significantly higher fruit and vegetable intake, but at the 1-week follow-up, only the "5aday" group's intake remained elevated when compared to both baseline and the control group. Heatherington et al[97] prescribed an intervention that had participants eat a meal within 1 of 4 circumstances; alone, with strangers, with friends, and watching television. Among the 4 exposures, energy intake was found to be significantly higher while watching television or eating with friends, when compared to eating alone. Kirk et al[95] measured multiple dietary outcomes at week 4 and week 12 of their intervention which involved daily consumption of a ready-to-eat breakfast cereal. When compared to the control group, the experimental group reported a significant decrease in saturated fat at week 4. A decrease in fiber intake was noted within the experimental group at both time points, but this change was not significantly different from changes observed in the control group. The experimental group's protein intake significantly increased between baseline and week 4 and baseline and week 12, although only the change at week 12 was significantly different compared to the control group. There was no significant change in added sugar intake at any time point, for either group. Judah et al[103] reported a reduction in SSB intake for both the diet drink implementation intentions group as well as the water implementation intentions group, though the reduction was only significant for the former group, and the difference in SSB reduction was not significant between groups.

Six of the included studies disclosed enough information to calculate the standardized effect size using Cohen's d formula.[90] Clifford et al[101] reported on total servings of fruit and vegetable intake which produced the smallest effect size of 0.04, while Kirk et al[95] reported the highest effect size of 0.98 for fat intake. Among all 6 studies the average effect size was 0.26.

Study Quality

Table 1.3 displays the quality rating for each included study. Four of the 9 studies received a designation of "positive" in terms of study quality.[99,100,102,103] Correspondingly, 2 of these studies scored perfectly by receiving a positive designation for each of the 10 questions asked by the QCC.[102,103] The remaining 5 studies were given a "neutral" designation and no studies received a "negative" rating. The study evaluated to have the lowest quality was Park et al,[96] which used time-restricted eating as an intervention. The question most commonly missed by each of the studies was a disclosure of funding or sponsorship source. The only item which every study addressed positively was the method of handling and disclosing withdrawals.

DISCUSSION

The aim of this systematic review was to assess the efforts, analyze the methods, and evaluate the effectiveness of intervention trials that employed ETL interventions among young adults. The majority of studies identified from this effort were RCTs, and among those, most utilized a health behavior theory as a rationale for their intervention. While no 2 studies employed the same intervention protocol, 4 studies used an implementation intentions approach that had participants write out a personalized, simple directive for how to improve a component of their diet, or were provided with this simple directive, and would carry it on their person throughout the study. Three of these 4 studies reported significant dietary behavior changes in the experimental versus control groups. These findings are congruent with a previous study exploring the effect of implementation intention interventions on dietary habits, wherein moderate to small effects were reported for including healthier foods in the diet, as well as reducing unhealthy eating patterns.[104] Another study compared the effects of 2 types of implementation intention approaches and a basic dietary and self-weighing goal setting approach on weight and diet-related outcomes among college students. While this study did not detect significant effects for either implementation intentions groups on the participants' HEI score, it was noted that both of these groups exhibited more goal-congruent behavior over the intervention period compared to the basic goal setting group.[105] Only 3 of the 9 studies included in this review failed to observe significant improvements in selected dietary markers, within and between experimental and control groups. This systematic review of ETL intervention approaches to dietary intake among young adults addresses an important gap given that this life stage generally has poor diet quality, which has been linked to increased future risk for chronic diseases.

A small-changes approach to health improvement via ETL interventions is a concept that has been applied to research previously, with varying degrees of success, but notably does not have a standardized or agreed-upon definition. Lally et al[56] conducted an intervention among 104 adults with obesity in which participants in the experimental group were instructed to read a brief leaflet; a list of 10 simple and practical tips that promoted dietary energy reduction, food intake self-awareness, and routine. In this instance, significant weight loss was reported after 8 weeks, with the intervention condition losing an average of 2.0 kg while the control reported a 0.4 kg loss. At a 32-week follow-up, the between-group difference remained significant.

Findings from Lally et al conflict with another systematic review that sought weight management interventions where participants had been instructed to perform actions that resulted in a caloric deficit of 200 kcals per day.[86] The included weight gain prevention trials observed an aggregate loss of 0.7 kg between groups at program end, not considered effective for weight loss, although may offer initial evidence in support of weight gain prevention. An additional study following a single cohort of 47 residents of Louisiana, most of whom lived in rural areas and were older than 50 years, failed to observe any changes in dietary patterns after a 4-week program that taught behavior change using a "small-changes" framework.[106]

Based on these previous studies, there is inconsistent evidence regarding the value of a simple change approach to improving health. Principally, there is general discordance over how "simple changes" are defined and operationalized for study purposes. Graham et al[86] set this definition as any action that prompted a daily 200 kcals reduction. Hill et al[87] proposed a similar definition but at 100 kcals per day. Adhikari and Gollub[106] tautologically referred to it as "conscious small changes in lifestyle behaviors" and required participants to complete a minimum of 6 hours of coursework over 4 weeks. Furthermore, a small changes approach is more commonly applied to weight-centered outcomes rather than improving diet quality. This systematic review puts forward an operating definition of "small behavior change" that expects performance of at least 1 reportable behavior that requires minimal time to learn and perform. Furthermore, this review departs from previous research assessments by placing the locus of change on diet quality, rather than weight.

At its core, the small behavior change approach considers operable actions that are within the control of the individual in spite of circumstance or setting, and there is evidence and rationale for this approach. For one, eating environments can be extraordinarily complex given personal circumstances and available food options, but opportunity to learn about and navigate simple, personalized approaches to dietary improvement are considered feasible and effective.[107] Second, choosing between broad, environmental interventions and small-change, ETL interventions is a false dichotomy. These can be conducted in tandem with one another, with small-changes potentially contributing to reduce or reshape the environmental factors that may adversely influence diet quality.[87] Third, when individuals feel a heightened sense of ability to act, such as through easily understood or relatable behavior changes, they are more likely to act and sustain action.[108,109]

The findings from this review suggest that a small-change, ETL intervention approach that focuses on improving diet quality within young adult populations can provide benefit from minimal effort. Of the 9 studies identified, 5 reported significant improvements between their intervention and control groups in their selected dietary markers. With the exception of Hetherington et al[97] that prescribed changes to the eating environment rather than changes in dietary content, the other 4 studies[95,98–100] exhibited 2 common qualities. First, each intervention used an implementation intentions or small directive dietary prompt which resulted in significant benefit to their experimental groups, with respect to changes in dietary intakes. Although Judah[103] only reported a significant within-group reduction of SSB intake but no significant difference between groups, the authors noted this may be attributed to the study design wherein both groups targeted a reduction in SSB intake, albeit through different approaches (diet beverages versus water). A second common quality among these 4 studies is that their interventions applied a focused behavioral objective; modifying intake of either fruit and vegetables, SSBs, or fat.[98–100,103] When it comes to dietary management, having a narrower focus of established goals, at least initially, can plausibly increase perceived behavioral control and elevate chances for successful change.[66,108,109]

Follow-up assessments are useful for diet-related studies to assess sustainability of effects, as any purported benefit that cannot be maintained once the intervention period ends is likely going to encounter problems with translational research for practical effect.[55,110] Only 3 of the studies in this review had follow-ups after the intervention period ended, with Kirk et al[95] measuring intake again at 3 months, Clifford et al[101] at 4 months, and Ungar et al[98] at 1 week. With a relatively short follow-up, Ungar et al reported a fruit and vegetable intake still significantly higher compared to the control. However, intake had decreased and it is unknown whether any improvements would have disappeared after a few more weeks. Clifford et al had the longest follow-up with no observed improvements, but this was a likely scenario given the failure to report any dietary improvement post-intervention. Kirk et al reported significant protein increase in the experimental group at a 3-month follow-up, compared to the control group. While that suggests sustainability in practice, the study does not report whether the specific intervention (required consumption of breakfast cereal) was continued post-intervention.

Thus, it is unknown if the sustained change in dietary intake was due to consumption of breakfast cereal or some alternative eating behavior.

In addition to observing statistical significance between groups within studies, we can further assess the relevance of ETL interventions through analysis of effect size, using a standardized measure previously used in diet-related studies for both diet quality and weight loss.[111,112] It is generally regarded that if group means don't differ by at least 0.2 standard deviations, the difference in selected outcomes between the groups is likely not meaningful, even when statistically significant.[112] As ETL interventions are simple by nature and small in their approach, we would not anticipate many moderate to strong effect sizes, a notion supported by an average effect size of 0.26 among all studies included in this review. Regardless, a few outcomes yielded relatively impressive effect sizes given the nature of the study's intervention. Three studies reported an effect size greater than or equal to 0.3 for improving fruit and vegetable intake, or reducing SSB intake.[98,100,102] With the exception of Clifford et al,[101] every study from which effect sizes could be calculated contained at least 1 outcome whose between group differences would not be considered trivial. The intervention by Kirk et al[95] generated the largest effect size for reducing dietary total fat through the daily introduction of a breakfast cereal, a low-fat food. However, this result should be interpreted with caution as a reduction in all forms of fatty acids was observed, including more desirable mono- and poly-unsaturated fatty acids. The authors also noted a pre-post decrease in dietary fiber intake in the experimental group, but the difference was not statistically significant compared with the control.

Among the 3 studies that did not see significant improvement, Park et al[96] lacked a control group and was relatively low-powered with only 33 participants, limiting generalizability and validity of findings. The other 2 studies by Clifford et al[101] and Pope et al[102] had a common feature of implementing a media platform to communicate health-based messages. While Clifford et al did not measure compliance, only 59% of the original participants completed the 4-month follow-up survey, though by the authors' calculations, the sample size was large enough to provide 90% power to detect changes in participants' nutrition knowledge through the cooking program intervention. In Pope et al,[102] both the social media and wearable technology interventions were rated high by participants in terms of feasibility and interest, and all completed their allocated treatments.

These 2 studies alone are insufficient to dismiss the effectiveness of an ETL intervention that takes advantage of media channels to deliver health messages. Prior studies targeting different population groups have reported successful health changes utilizing media-based approaches. For example, in a study by Caplette et al[113] involving predominantly middle-aged Caucasian women (mean age = 42 years), the experimental group read short blog posts weekly over the course of 6 months, which resulted in significant improvement in fruit and vegetable intake compared to the control group without access to the blog. Another study with a similar population reported significant weight loss and increased fruit and vegetable intake in the group who listened to 24 episodes of a theory-driven podcast on weight loss, over the course of 12 weeks, compared to the control group.[114] Whether the difference between the studies in our review versus these latter 2 examples is a matter of exposure length or "content dosage", or perhaps differences in population demographics, remains to be explored. Furthermore, whether interventions are conducted in-person or through technology and media, both approaches demonstrate significant but minimal effects for improving the health of young adults.[115]

Also worth consideration is the 1 study in this review which functionally required a food prescription, by instructing participants to consume a specified food (breakfast cereal with milk) daily over the course of the study protocol.[95] While this study found an increase in protein and reduction of saturated fat intake compared to the control, a reduction in fiber intake was also observed in the experimental group. In most circumstances, a reduction in fiber intake is considered a reduction in diet quality. In another study of similar design, participants were randomized to consume either an ounce of almonds before dinner or an isocaloric amount of cheese over the course of 8 weeks, but no change in fiber, fat, protein, or energy intake was observed between the groups.[116] This latter study experienced an extremely high rate of attrition, perhaps broadcasting one of the critical limitations of studies that require such rigidity in eating patterns. Reasonably, the best dietary approach is one which meets nutritive needs of the participant, and can be maintained in the long run. Allowing greater flexibility in dietary choices while generally following healthy dietary principles is likely to be more acceptable to individuals. Although a rigidly prescribed dietary pattern may appear simple in theory, this approach is not in concordance with successful adherence strategies according to behavior change theories and longitudinal studies of this nature often suffer from extraordinarily high attrition rates.[51,66,85,108]

A few of the studies reported high attrition rates, with more than 50% of those originally enrolled dropping from the study before the final point of data collection.[99–101] The reasons for these attrition rates were not usually offered. One study noted attrition was due to participants failing to provide a personal code necessary to identify their questionnaire for data inclusion and analysis.[99] Another study excluded subjects reporting 4+ servings of fruits/vegetables at baseline to ensure the 2 study arms ("just 1 more" and "5aday") communicated different messages.[98] In general, it was uncommon for any of the included studies to comment on or verify compliance rates within the study. It is possible that this was an intentional choice in the study design, on the presumption that a simple behavior change study would not require a compliance check.

When interpreting the overall results of this review, one should consider the makeup of the populations as well as the diversity of geographical locations studied. Each of the nations represented within the included studies may have different food environments, cultural norms, and economic challenges that could influence the dietary habits of young adults beyond the prescribed ETL intervention. The general audience of interest as young adults is a broad categorization with subgroups engaged in various activities, living conditions, and circumstances. We acknowledge that those who attend college, or work, or experience different living conditions will have varied capacities for implementing dietary behavior changes. Additionally, the majority of the participants within the included studies were female, and few studies reported demographic data such as socioeconomic status or racial and ethnic makeup, all of which limits the generalizability of the findings among young adults. This is a common problem in many studies that should be addressed when recruiting and sampling populations of interest, where health-related studies sample Caucasian females disproportionately, albeit if not intentionally.[84,115]

One more notable gap from the literature is that not all components of diet quality were represented, as overall diet quality is measured according to summary indices that account for multiple aspects of the diet and their relationship to one another, such as the HEI-2015.[2] Notably absent from this review was an assessment of ETLs that address sodium, dairy, plant-based proteins, and refined grain intake. The diets of young adults are typically low in fruit and vegetables, plant-based protein, dairy items, and high in added sugars, refined grains, and sodium intake, thus justifying their need to be assessed.[117]

Limitations for this systematic review may include the inclusion criteria and operating definition for ETL interventions, given the lack of consensus for how to best define a small-changes approach to health improvement, and a lack of scientific consensus means there may be a more valid way to capture this approach. At present, a small-change approach to improving dietary intake is justified, but how to best implement it is limited by current data.[56,86,87] Easy-to-learn interventions are based largely on time required to learn and successfully perform a behavior, but this fails to identify studies that could address important personal factors that also impact diet, such as socioeconomic status, readiness to change, or education level. Although chosen based on the results of a pilot search, the key terms we selected may have limited access to studies that fit this review's definition of an ETL intervention. Furthermore, given the limited number of studies available, all were included that met the criteria regardless of study power or quality.

IMPLICATIONS FOR RESEARCH AND PRACTICE

When discussing health promotion methods through the lens of simple behavior changes, researchers need to carefully consider how they are defining this approach. While it may not be possible to centralize a definition of what comprises simple behavior change, efforts can be made to clarify descriptions about what this practically looks like within the study. This review provides evidence for how changes in aspects of diet quality are achievable within young adult populations through performance of at least 1 reportable behavior that requires minimal time to learn.

Additional efforts in future studies to recruit a more broadly diverse body of young adults may help increase the generalizability of findings, whether those participants are working, in college, or still assessing their course in life. At present, most studies tend to oversample from

Caucasian females. While there is some evidence from this review to demonstrate the effectiveness of an ETL intervention approach, there may be inherent shortcomings or barriers for this approach when applied to specific populations.

Furthermore, while our review did not yield any discernible patterns on the use of theory and diet-related outcomes, designing an intervention that uses a theoretical framework is still encouraged. Broadly speaking, interventions that incorporate theory are more likely to achieve significant results than those which do not.[67] This review's focus on ETL interventions as a means to improve diet quality is itself justified within health behavior theory, used to design numerous health interventions that yielded positive and sustained effects within their study population.[68]

Each of the studies assessed a measure of diet quality, and with 1 exception, all captured additional data that was not related to dietary intake. The most commonly assessed component of diet was fruit and vegetable, with fat, added sugar, total protein, whole grain, and SSB intake also assessed. These are important components of diet quality, but as previously stated, there are additional elements of diet quality that need consideration given their association to the diets of young adults and chronic disease risk, including refined grains, sodium, dairy, and plant-based proteins. It is also worth noting that interventions can be tailored to improve diet quality independent of weight outcomes, as only 3 studies within this review tracked weight of the participants. Given the population of interest, this approach may be preferable for 2 reasons. First, there is evidence of benefit for interventions that deliberately ignore any emphasis or measure of weight loss, opting to promote diet quality through modification of dietary choices and behaviors.[118] Second, weight-centered approaches may increase risk for eating disorder (ED) development among at risk populations. Data indicate higher-than-average prevalence of ED symptoms among young adults compared to the general population, and the average age of onset for various EDs range from 18.9 to 25.4 years of age.[119,120]

We reiterate that small-scale and individualized efforts to promote healthy behavior change need not be in conflict or at odds with large, structural changes to the food environment. There may be ways in which both small and large changes can be mutually supportive of one another. Cost-effective strategies that maximize positive outcomes from limited resources may need to be explored and developed.

In the challenge of promoting population-level diet quality, data from this review indicate that ETL interventions can be counted as a tool that may effectively assist in this endeavor. What these interventions may lack in scale as currently designed, they may make up for in efficacy by empowering individuals to make changes despite setback or circumstance. At present, there is no reason to suspect this ETL intervention approach would be at odds with or be detrimental to efforts on a broader and more systemically applied scale. Rather, it can be another tool in the pantheon of interventions that healthcare and public health professionals have to assist individuals achieve more optimal health.

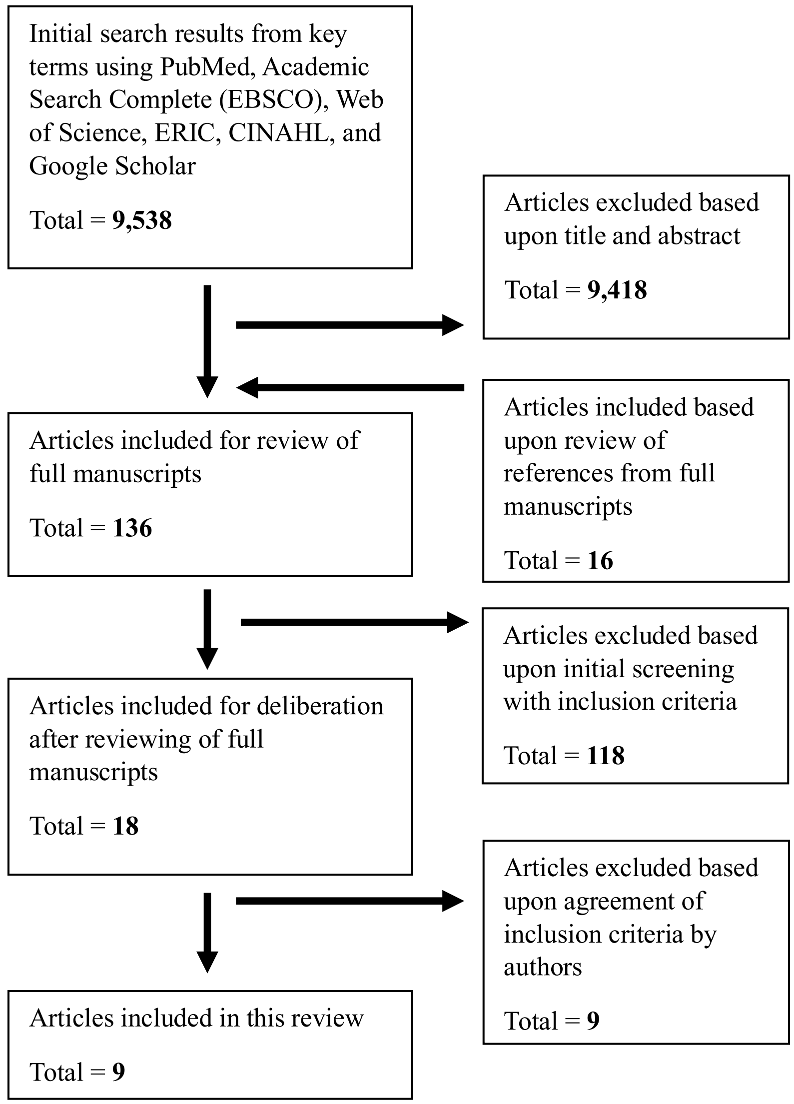

Figure 1.1 Flow chart for the article search process, from initial search results to included articles. EBSCO, Elton B. Stephens CO (company); ERIC, Education Resources Information Center; CINAHL, Cumulative Index to Nursing and Allied Health Literature.

TABLE 1.1: Study design characteristics of included studies

Year	Author(s)	Country of Origin	Study Title	Theory Involved	Study Design	Control Group	Description of Simple Intervention	Timeline of intervention
2004	Armitage, C. J.	United Kingdom	Evidence that implementation intentions reduce dietary fat intake: A randomized trial.	TPB	RCT, with a control and experimental group	Passive control group	Using a single note card, participants write a detailed description for how to consume less fat in the diet, and carry this card on their person.	1 month (pre/post assessment)
2007	Armitage, C. J.	United Kingdom	Effects of an implementation intention-based intervention on fruit consumption.	TPB	RCT, with a control and experimental group	Passive control group	Write and carry an implementations card stating when and where to eat an extra piece of fruit each day for the duration of the study.	2 weeks (pre/post assessment)
2009	Clifford, D., Anderson, J., Auld, G., & Champ, J.	United States	Good Grubbin': Impact of a TV Cooking Show for College Students Living Off Campus.	SCT	RCT, with a control (n=51) and experimental group (n=50)	Viewing four, 5-minute programs on sleep disorders	Watching 15-minute episodes of a cooking program, once a week for four weeks.	4 weeks, with a follow-up at 4 months
2006	Hetherington, M. M., Anderson, A. S., Norton, G. N. M., & Newson, L.	United Kingdom	Situational effects on meal intake: A comparison of eating alone and eating with others.	None	Repeated measures (x4 conditions for each participant)	Repeated measures design, so no functional control group	Consuming meals in one of four settings; being alone, with friends, with strangers, and watching TV.	4 eating appointments (Spaced over 2 weeks)
2020	Judah, G., Mullan, B., Yee, M., Johansson, L., Allom, V., & Liddelow, C.	United Kingdom	A Habit-Based Randomised Controlled Trial to Reduce Sugar-Sweetened Beverage Consumption: The Impact of the Substituted Beverage on Behaviour and Habit Strength.	None	RCT, with a water group (n=79) and a diet drink group (n=57)	Comparison, water-consuming group	Writing out an implementation intentions card that the participant carries, which describes when and where participants usually purchase sugar-sweetened beverages, and how they plan to swap these for non sugar-sweetened beverages.	2 months (pre/post assessment)
1997	Kirk, T. R., Burkill, S., & Cursiter, M.	United Kingdom	Dietary fat reduction achieved by increasing consumption of a starchy food—An intervention study.	None	RCT, with a control (n=22) and experimental group (n=26)	Passive control group	Consumption of 60 grams of a ready to eat breakfast cereal (Kellogg's Corn Flakes, Rice Krispies, or Special K) with 1% milk each day.	4 weeks, with a follow-up at 3 months

2021	Park, S.-J., Yang, J.-W., & Song, Y.-J.	South Korea	The Effect of Four Weeks Dietary Intervention with 8-Hour Time-Restricted Eating on Body Composition and Cardiometabolic Risk Factors in Young Adults.	None	Single arm feasibility study	No control group	Select an 8 hour length of time in the day, and restrict all eating activity to that span of time for the study duration.	4 weeks
2019	Pope, Z. C., Barr-Anderson, D. J., Lewis, B. A., Pereira, M. A., & Gao, Z.	United States	Use of Wearable Technology and Social Media to Improve Physical Activity and Dietary Behaviors among College Students: A 12-Week Randomized Pilot Study.	SCT/SDT	RCT, with a comparison (n=19) and experimental group (n=19)	Comparison, included a content-identical Facebook group, without a smartwatch	Wear a Polar M400 smartwatch and enroll in a Facebook group that promotes evidence-based health and diet education tips twice a week.	12 weeks (Baseline, 6 weeks, 12 weeks)
2013	Ungar, N., Sieverding, M., & Stadnitski, T.	Germany	Increasing fruit and vegetable intake. “Five a day” versus “just one more.”	SDT	RCT, with a control (n=29), 5aday group (n=28), and "Just one more" group (n=27)	Instructions to "eat as usual during the next week".	Simple instruction to participants to either "eat 5 a day of fruits and vegetables" or "eat one more serving of fruit or vegetable today than you usually do"	1 week, with a follow-up at 1 week

RCT, Randomized Controlled Trial; SCT, Social Cognitive Theory; SDT, Self-determination Theory; TPB - Theory of Planned Behavior

TABLE 1.2: Population descriptions, effect size, and outcomes of included studies

Reference Study	Population description	Participants	Dietary outcome(s)	Standardized effect size (Cohen's d)	Alternative outcomes measured	Summary of diet-related findings
Armitage, C. J.	UK citizens recruited from a company, 18-75 years (Mean age=33)	N=264 (159 women / 106 men); No race/ethnicity data reported	Fat intake (g/day) Saturated fat intake (g/day) Fat intake (%)	0.24 0.22 0.1	TPB variables (attitude, subjective norm, perceived behavioral control)	All measures of fat intake significantly decreased within the EXP, but not the CON. Fat intake also decreased significantly between groups. Differences could not be explained by motivation between both groups.
Armitage, C. J.	UK college students, 18-20 years (Mean age=19.5)	N=120 (96 women / 24 men); No race/ethnicity data reported	Fruit intake (Pieces of fruit, by brief FFQ)	0.38	TPB variables (attitude, subjective norm, perceived behavioral control), behavioral intention	Fruit intake significantly increased within the EXP, but not the CON. Change in fruit intake was also significant between groups.
Clifford, D., Anderson, J., Auld, G., & Champ, J.	US college students from upper level non-health courses	N=101 (74 women / 37 men); (94 living off campus / 7 elsewhere); (74 do not eat at dining hall / 27 eat at dining hall); no race/ethnicity data reported	Total servings of FV intake (by short FFQ)	0.04	Program feedback survey, Adherence questions, Knowledge/Attitudes/Behaviors related to FV intake and cooking	No significant change within or between groups for FV intake, at neither post- nor follow-up assessment.
Hetherington, M. M., Anderson, A. S., Norton, G. N. M., & Newson, L.	Staff and students at a UK university, 18-54 years (Mean age = 28.3)	N=37 (16 women / 21 men); no race/ethnicity data reported	Energy intake (kcals) with sub analysis of added sugar and high fat foods	Not available[a]	Participant behavior (videotaped and then coded), Duration of the meal, Percentage of time spent eating, Memory test of how much food eaten, Appetite, Mood.	Energy intake was significantly higher when watching TV or eating with friends compared to eating alone. Added sugar and high fat foods were the only food choice significantly higher, but only when eating with friends.
Judah, G., Mullan, B., Yee, M., Johansson, L., Allom, V., & Liddelow, C.	UK and US citizens recruited through online crowdsourcing website, age 18-74 (Mean age=31.5)	N=158 (69 women / 67 men); Predominantly White (n=49), Asian (n=7), Black (n=7), Other (n=16)	SSB intake (portions/week)	Not available[a]	Habit (automaticity), Hedonic liking	Significant reduction in SSB consumption in the diet drink group, with a large and nonsignificant reduction in the water drink group. No significant difference in reduction between groups.

Kirk, T. R., Burkill, S., & Cursiter, M.	College undergraduates from UK college, age 17-30 (Mean age=20)	N=48 (46 women / 2 men); no race/ethnicity data reported	Protein (g/d) Fat (g/d) [SFA, PUFA, MUFA] Sugars (g/d) Fiber (g/d)	0.25 0.98 0.08 0.43	Weight and BMI	SFA intake saw a significant reduction from baseline in the EXP at both 4 and 12 weeks, and at 4 weeks when compared to CON, with no observed changes within the CON. There was a corresponding significant increase in protein from baseline at 4 and 12 weeks, and at 12 weeks when compared to CON. NS change in sugar for both groups, and significant reduction in fiber intake from baseline within EXP at 4 and 12 weeks, but not when compared to CON.
Park, S.-J., Yang, J.-W., & Song, Y.-J.	Young adults in South Korea without a metabolic disorder or recent 10% weight change, age 18-28 (Mean age=22.5)	N=33 (25 women / 8 men); no race/ethnicity data reported	Added sugar (%) SFA (%) Protein (%) Energy intake (%)	Not available[a]	Body composition, BMI, waist circumference, insulin, blood glucose, lipid panel, HOMA-IR, physical activity, sleep quality, other indeterminate lifestyle factors.	NS differences in added sugar and SFA intake between baseline and termination of the study
Pope, Z. C., Barr-Anderson, D. J., Lewis, B. A., Pereira, M. A., & Gao, Z.	College undergraduates from a Midwest University in the US, age 18-35	N=38 (28 women / 10 men); no race/ethnicity data reported	Fruit intake (cups) Vegetable intake (cups) Whole grains (oz eq) SSB (calories)	0.09 0.07 0.07 0.35	Intervention interest, Use and Acceptability, Adherence, Retention, physical activity, cardiorespiratory fitness, BMI, body composition, social support, enjoyment of health-related behaviors, perceived health behavior barriers, outcome expectancy, Interest/Enjoyment	No significant changes reported between both groups in FV intake, whole grain, and SSB intake, nor were significant changes reported from baseline to 6 and 12 weeks for both groups with all diet-related outcomes.

Ungar, N., Sieverding, M., & Stadnitski, T.	German college undergraduates recruited on campus (Mean age=23.4)	N=84 (71 women / 13 men); no race/ethnicity data reported	FV intake (servings)	0.3	None	Between baseline and the end of the intervention, all three groups had significantly higher FV intake, but at the 1-week follow-up only the 5aday group had significantly higher FV intake compared to its baseline. At follow-up, only the 5aday group had significantly higher FV intake compared to CON. NS difference in FV intake between all groups from baseline to follow-up.

TPB - Theory of Planned Behavior; EXP - experimental group; CON - control group; FFQ - food frequency questionnaire; FV - fruit and vegetable; SSB - sugar sweetened beverages; SFA - saturated fatty acids; PUFA - polyunsaturated fatty acids; MUFA - monounsaturated fatty acids; BMI - body mass index; NS - non significant; HOMA-IR - Homeostatic Model Assessment for Insulin Resistance

[a]Data necessary to calculate effect size (standard deviations, t-values) were missing.

TABLE 1.3: Quality Assessment of Included Studies using the Quality Criteria Checklist (QCC)

Validity Questions	Armitage (2004)	Armitage (2007)	Clifford, Anderson, Auld., & Champ (2009)	Hetherington, Anderson, Norton, & Newson, (2006)	Judah, Mullan, Yee, Johansson, Allom, & Liddelow (2020)	Kirk, Burkill, & Cursiter (1997)	Park, Yang, & Song, (2021)	Pope, Barr-Anderson, Lewis, Pereira, & Gao (2019)	Ungar, Sieverding, & Stadnitski, (2013)
1. Was the research question clearly stated?	Yes	Yes	Yes	Unclear	Yes	Yes	No	Yes	Yes
2. Was the selection of study subjects/patients free from bias?	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	No
3. Were study groups comparable?	Yes	Yes	Yes	Unclear	Yes	Unclear	N/A	Yes	Yes
4. Was method of handling withdrawals described?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
5. Was blinding used to prevent introduction of bias?	Yes	Yes	Unclear	N/A	Yes	No	Unclear	Yes	Unclear
6. Were intervention/therapeutic regimens/exposure factor or procedure and any comparison(s) described in detail? Were intervening factors described?	Yes	Yes	Unclear	Yes	Yes	Yes	Unclear	Yes	Yes
7. Were outcomes clearly defined and the measurements valid and reliable?	Yes	Yes	Yes	Unclear	Yes	Unclear	Unclear	Yes	Yes
8. Was the statistical analysis appropriate for the study design and type of outcome indicators?	Yes	Yes	Yes	Unclear	Yes	No	No	Yes	Unclear
9 Are conclusions supported by results with biases and limitations taken into consideration?	Yes	Yes	Yes	No	Yes	No	Yes	Yes	Yes
10. Is bias due to study's funding or sponsorship unlikely?	Unclear	Unclear	Unclear	Unclear	Yes	No	Yes	Yes	Yes
Overall Assessment	+	+	Ø	Ø	+	Ø	Ø	+	Ø

+	Indicates that the report has clearly addressed issues of inclusion/exclusion, bias, generalizability, and data collection and analysis.
Ø	Indicates that the report is neither exceptionally strong nor exceptionally weak.
–	Indicates that these issues have not been adequately addressed.

RESEARCH CHAPTER 2: Associations of Psychological Stress and Food Security with Diet Quality in Full Time College Students

INTRODUCTION

Entry into college life represents a significant developmental milestone, characterized by expanded autonomy, development of self-identity, and formation of psychosocial attributes that are associated with health behaviors.[26] Among the newfound opportunities, there will also be new challenges, including the responsibility to manage and care for their own health. Diet plays a significant role in the maintenance of health and prevention of chronic illness, and the dietary intake of college students may be influenced by numerous factors, including income level and food access, personal knowledge of health, and psychological stress, the latter of which is generally negatively associated with diet quality.[121–123]

Evidence from studies evaluating intake practices among college students suggest suboptimal dietary patterns. In nationwide surveys of college student behaviors, 18.7% reported eating more than two servings of fruit per day, and 36% reported similar intake for vegetables.[36] Previous studies report that teenagers and young adults consume more calories per day from sugar-sweetened beverages (SSB) than any other age demographic, with average daily energy intake from all SSBs for young adults (ages 20 to 34) exceeding 340 kcals.[37,38] Even among students pursuing health-related majors, prior research indicates that few manage to meet dietary recommendations.[39]

Diet quality scores are consistently low for college students as assessed by the Healthy Eating Index (HEI), a robust scale scored from 0 to 100 to measure compliance with dietary guidelines, recommending a minimum score of 80 for reduced risk of chronic illness.[40] Nationwide reporting using standardized recalls methods observed an average HEI score of

64.8±0.2 among the generalized student body.[41] Yu et al[124] reported slightly higher scores among college freshmen when compared to the national average of adults and children (60.9 vs. 58.3, $P < 0.05$). Hispanic freshman scored much lower, with an average HEI of 54.9.[42] Even among students who had recently completed an introductory nutrition course, the mean score was 68.3±18.3.[43] It is difficult to discern how diet quality among college students has changed over the previous decade, though the earliest uses of the HEI measure among college students reported similar low scores.[28]

Improving diet quality in college students requires management of both personal constraints, such as unhealthy snacking behaviors, low motivation to change, and psychological stress, and environmental constraints, such as limited opportunity or availability of resources for preparing healthy meals, abundance of fast food options, and issues of food security.[30,31,46,47] Food security refers to the availability of nutritionally adequate, safe foods, or the ability to acquire acceptable food in socially acceptable ways.[124] Food insecurity is therefore suspected to have a negative impact on diet quality, though data report inconsistent associations with poor dietary outcomes.[125] However, among more rigorous studies which draw from randomized samples and use validated food security measures, there are significant and positive associations between food security and diet quality.[126,127] Beyond issues of diet quality, observational data report a significant and direct association between food insecurity and poor academic performance.[128,129]

Psychological stress is another widespread factor that is personal by nature and has potential to significantly impact dietary patterns. Nationwide, 46% of the youngest surveyed age (<35 years old) of American adults reported experiencing stress levels that inhibited their ability to function, a percentage higher than any other age group.[130] The number of college students who reported significant stress as a result of their studies increased over the past decade, with 88% reporting a stressful school life, and 45% reporting the highest stress levels.[131] Stress levels may fluctuate, peaking when transitioning into college or when preparing to graduate, and can be attributed to coursework demands, lifestyle practices, social networks and engagement, and financial circumstances.[132]

The precise effect and mechanism of action for psychological stress's influence on diet is still under study, though it is generally regarded as having a negative impact on dietary habits of college students. For example, there is more frequent reporting of meal skipping, overeating, fast food intake, and consumption of added sugar intake in students categorized as having high stress, compared to similar student populations with low reported stress.[133] Emotional eating, a behavioral pattern of eating in response to stress, anger, and depression, is associated with increasing levels of stress among students with a low body mass index (BMI).[134] In a study not specific to college students but conducted among a young adult population, greater perceived stress among females predicted selection of larger portion sizes and greater energy intake.[135]

The combined effect of food security and psychological stress on diet quality in college students is not well studied, though evidence suggests there is a relationship between these two factors. Limited data from longitudinal and cross-sectional studies report food insecurity as a contributor to psychological stress among college students.[136] Qualitative data exploring themes of stress and food security demonstrate how limited food access directly contributes to stress, hopelessness, and interference with daily life in college.[124] Given these associations, it is plausible that food security and stress may play an interactive role in contributing to diet quality among college students.

Though stress is generally regarded as having a negative impact on diet quality, few studies have explored the relationship among college students, and fewer have sought to quantify this relationship with a measure of diet quality as robust as the HEI-2020. Furthermore, given the association between food security and stress, additional research is needed to identify whether food security moderates the relationship between stress and diet. Therefore, the aim of this study is to examine the association between perceived stress and diet quality in a diverse population of college students, as well as explore whether food security status moderates the association between perceived stress and diet quality.

METHODOLOGY

Participants

This study is a cross-sectional, secondary analysis using baseline participant data from an intervention trial to improve the diet quality of young adults enrolled full time in college (trial registration: ISRCTN 53920728). The study received IRB approval from the University of California, Irvine and all participants provided consent. Participants were recruited from August 2022 to March 2023, from two universities in Southern California with large and ethnically diverse student populations. Recruitment was conducted through mass email blasts within departments, announcements in general elective courses, flyers posted on campus, and word of mouth referral from students who participated. Eligibility for participation required students be 18 to 25 years of age, enrolled full time as a student at their university, fluent in English, without medical conditions or allergies that would require modification of diet, without eating disorder symptoms, and with a diet not currently complying with dietary guidelines.

For pre-screening purposes, interested students completed online surveys through the Research Electronic Data Capture system (REDCap) so that the research team could determine eligibility. This included i) the SCOFF questionnaire which is considered an effective screening instrument for detecting eating disorders, asking the participants five yes-or-no questions, where two or more answers for "yes" on any question indicate a likely case of having an eating disorder,[119,120,137] and ii) a 7-item diet screener survey adapted from the Rapid Eating and Activity Assessment for Patients Short version (REAP-S), a validated survey that can accurately assess food group servings which characterize a healthy diet.[138] Students who scored higher than 18 on the diet screener were likely consuming a better-than-average diet and thus excluded from participation, allowing for participation from students more likely to benefit from the study intervention, while also reducing bias from social desirability.[139] If eligible after completing this screening survey, students were provided additional study information and asked to provide their best contact information if interested in participating.

Procedure

Each eligible student was contacted on random days and invited to complete two non-consecutive interviewer-led, 24-hour dietary recalls using the Automated Self-Administered 24-hour recall tool (ASA24), a validated, free web-based program offered by the National Cancer Institute (NCI).[140] Completion of two diet recalls on non-consecutive days follows best practices to reduce risk of outliers and minimize within-participant variance in dietary data.[141] Students were also asked to complete a baseline survey on REDCap that collected information on individual demographics, food security, perceived stress, and readiness to change. Once this baseline survey and both diet recalls were completed, students were considered enrolled in the trial and then assigned to their treatment group.

Measures

Participant Demographics

Baseline demographic data included age, sex, self-reported weight and height, major of study, residency status, and race. Age was measured by number of years. Sex was recorded by sex assigned at birth, with three response options including “Male”, “Female” and “Intersex”, the latter referring to individuals who were born with any variation in sex characteristics not typical of males or females, due to chromosomal or gonad alterations.[142] Weight and height were self-reported and recorded in pounds and inches. Major of study was the students’ current declared major. Residency was captured from a list of options designating the students’ current living situation. Lastly, students self-identified race as either, “Asian or Asian American”, “Black or African American”, “Hispanic or Latino”, “White”, “American Indian or Native Alaskan”, “Middle Eastern/North African or Arab Origin”, “Native Hawaiian or Other Pacific Islander Native” or “Biracial or Multiracial”. Given the limited number of responses on the latter four racial categories, these were compiled together and labeled as “Other”.

Healthy Eating Index-2020

The 2020 Healthy Eating Index (HEI-2020) is a measure for assessing diet quality, and used to assess how well an intake pattern aligns with key recommendations for the Dietary Guidelines for Americans.[40,143] The HEI-2020 is a composite score made up of 13 components, nine of which promote dietary adequacy, while four focus on limiting intake of foods that contribute saturated fats, refined grains, added sugars, and sodium. The sum total of these components provides an indication of diet quality, scored from 0 to 100, with a higher score interpreted as better diet quality. Information collected from ASA24 recalls was linked to intake data through the 2017-2018 Food and Nutrient Database for Dietary Studies, allowing for subsequent calculation of HEI-2020 scores.

Perceived Stress Scale

Perceived stress of students was determined using the Perceived Stress Scale-10 (PSS-10), a 10-item questionnaire that asks questions about perceptions of stressful experiences in the past month, answered and scored from 0 to 40, with a higher score indicating higher stress levels. The PSS-10 has been consistently reported to be a valid and reliable indicator of perceived stress in adult populations.[144]

Food Security

Food security was assessed using the USDA-ERS's Food Security 6-item short form, where a higher score indicates lower food security (score range: 0-6).[145] Any student who scored ≥2 on the survey was designated as experiencing food insecurity, while those with scores of 0-1 were categorized as experiencing food security.

Statistical analysis

Survey data was assessed for completion, with duplicate or incomplete records being removed. If students failed to complete the two baseline 24-hour recalls, the primary outcome measure could not be computed and they were thus removed from study. Survey data was collected through REDCap, a web-based survey and data management application hosted by the university, while ASA24 was used to collect dietary data through 24 hour-recalls, and records within both platforms were matched using a unique four-digit code ID assigned to students at the start of the study. Once records were matched, diet recall data was reviewed for outliers or incomplete information. Records were excluded from analysis if they reported extremely low mean daily calorie intake (<600 kcals for women; <650 kcals for men) that indicated likely underreporting and thus, unreliable data.

Descriptive statistics were used to present sociodemographic, HEI-2020, PSS-10 and food security data. Correlations between participant characteristics and HEI-2020 scores were assessed using Pearson's and Spearman's rho tests, for continuous and categorical variables, respectively. Univariate linear regression was used to analyze associations between PSS-10 as a predictor, with diet quality component and total scores as dependent variables.

Hierarchical multiple linear regression was conducted to test the main and interaction effects of PSS-10 and food security on HEI-2020 total and component scores. Age, BMI, and race were included as *a priori* covariates for model one, PSS-10 and food security categorization (Security vs Insecurity) for model two, and interaction of food security category and PSS-10 for model three. Statistical analyses were performed using the software *Statistical Package for the Social Sciences* (SPSS) version 29 for Windows. P-values < 0.05 were considered statistically significant.

RESULTS

150 students were initially enrolled in the study, 19 did not complete baseline surveys, and 17 did not complete two diet recalls, for a total of 114 included for analysis. Descriptive characteristics with corresponding average HEI-2020 total scores are reported in Table 2.1. The median±IQR age of students was 20.0±2.0, with a median BMI of 22.6±4.3. The majority of the students were female (82.5%) and there was broad diversity in self-identified racial groups. PSS-10 scores ranged from 8 to 32, with a mean±SD score of 19.0±5.3. The mean food security score was 1.0±1.8 and most students were classified as having food security (79.8%). There were no significant differences in HEI-2020 score by sex, residence, or food security status, but a

significant difference was identified according to self-identified race such that Asian students reported a significantly higher HEI-2020 score than White students (57.5±11.3 versus 48.3±13.2; p=0.025), and Hispanic students approached significance for a higher HEI-2020 score than White students (56.2±13.5 versus 48.3±13.2; p=0.056).

Results from Pearson's and Spearman's rho correlation tests are presented in Table 2.2. There were no significant correlations between HEI-2020 total score and any participant characteristic. However, food security score was significantly and positively associated with PSS-10, age, and BMI.

HEI-2020 total score was not associated with PSS-10 (β= 0.03 [95% CI: -0.449, 0.516]) in the univariate regression analysis, nor were any significant associations observed between each of the components of diet quality and PSS-10 (Table 2.3). However, the associations between PSS-10 and the sugar component score (β= -0.08 [95% CI: -0.161, 0.001]) as well as the total protein component score (β= -0.03 [95% CI: -0.058, 0.002]) approached significance, indicating a trend lower rating of compliance with dietary guidelines for sugar and protein intake in the context of elevated perceived stress levels.

Hierarchical multiple regression found no significant main effect of food security status, PSS-10, or their interaction on HEI-2020 total score (Table 2.4). There were also no main effects of food security status or PSS-10 on any of the HEI-2020 component scores. There was a significant interaction effect of PSS-10 x food security with the total vegetable score (β = -0.110, CI = -0.213, -0.007, p = 0.037) and the total protein score (β = 0.092, CI = 0.033, 0.158, p = 0.006) such that the models explained 11% and 13% of the variance in these components, respectively. Scatterplots subdivided by food security categorization show for the food insecure group, increasing PSS-10 scores correlate with poorer dietary compliance with total vegetable intake, but improved compliance with total protein (Figures 2.1 and 2.2).

DISCUSSION

Findings from this cross-sectional analysis report an average HEI-2020 score of 55.4±13.8 among all student participants, lower than a nationwide mean of 64.8±0.2, and well below the recommended score of 80.[40,41] Interestingly, there were no significant correlations between HEI-2020 score and the student characteristics age, sex, BMI, residence, and food security status, although a difference was noted between self-identified racial groups, such that Asian students reported significantly higher diet quality than White students. Food insecurity was reported among 20.2% of students, a figure that falls within range of previous studies assessing prevalence of food insecurity on college campuses.[146] The average PSS-10 score fell within the middle of the moderate stress range, as interpreted using the scale.[144] In contrast to previous studies that report associations between psychological stress and dietary patterns, this study failed to identify significant associations between students' perceived stress levels and overall diet quality, although the relationship with sugar and protein intakes trended towards significance. With respect to the combined effect of food security and perceived stress on diet quality, it was assumed that food insecurity would exacerbate the effect of stress and contribute to lower HEI-2020 scores. Contrary to expectations, no significant moderation effect of food security status was observed on the relationship between perceived stress and overall diet quality, although it was found to moderate the relationship with total protein and vegetable component scores. However, these moderation results were not uniformly negative, as elevated stress was associated with increased dietary compliance for total protein when food insecurity was present, but decreased dietary compliance for vegetable intake in the context of food insecurity.

This study's failure to report any significant associations between perceived stress and diet quality runs contrary to previous work, with 10 of 13 studies from a systematic review reporting significant, inverse associations between diet quality and stress within college students.[123] However, the majority of these studies were conducted outside the United States, and the one study that was within the United States also failed to report any significant associations between diet quality and stress.[147] Based on these findings alone, it cannot be concluded that the diets of U.S. college students are unaffected by stress, but it does prompt questions about responsiveness to stress. That college students experience elevated stress levels is well established, with 56% reporting chronic stress, and among those who attend mental health counseling services, 46.3% of visits center upon stress management.[148,149] But dietary responsiveness to stress can markedly differ between individuals, with some studies reporting decreased, increased, or no change to food intake.[122] Furthermore, the data reported in this study was collected throughout the academic year, and reported stress rates can cyclically fluctuate by time of year.[150]

In contrast to the consistently high rates of perceived stress, data reporting prevalence of food insecurity among college students fluctuate widely, ranging from 12.5% to 84%, and an average rate of 42% from peer-reviewed literature.[146] Capturing a more accurate picture of food insecurity is complex given the heterogenous nature of college settings and their students. Most peer-reviewed literature use USDA or other validated scales to measure food security, but studies are often conducted within urban, public 4-year institutions, and use convenience sampling that may bias results. Further complicating the matter is the temporal nature of food insecurity, where need may rise and fall in consequence of aid or funding that refresh during certain cycles.[151] At present, it seems more likely that lower food security is a matter of student circumstance, not institutional setting. Both urban and rural colleges report relatively similar rates of food insecurity, but students who live with family, have attended college for longer, or do not report government assistance are those who report higher food security.[146] While findings from this study coincide with nationally reported stress levels among college students, rates of food insecurity in this student population were lower than average reported rates.

Food security's general effect on diet quality is difficult to interpret from present literature, with inconsistent findings regardless of how diet quality is measured.[125] Whether examining SSB consumption, sugary or salty snack foods, fiber, or dairy intake, evidence does not consistently show significant discrepancies between food secure and food insecure students. The most consistent findings for a negative overall impact appear to include fruit and vegetable intake, but even here, there is variability. Studies report significant correlations between low fruit and vegetable intake and food insecurity,[152] while others only report low fruit and vegetable intake when housing circumstances differ,[127] and still, some studies report no difference in fruit and vegetable intake by food security status.[86,153] The food secure and insecure groups for this study reported HEI-2020 scores lower than 60, with no significant difference in scores between groups.

Though food security's impact on diet appears to have inconsistent outcomes, it is reasonable to presume that it has an interactive effect with psychological stress on diet quality. First, food security and psychological stress were significantly correlated in our student cohort, consistent with what has been observed in other studies,[136] including among a representative sample of U.S. college students.[152] Second, despite findings from this study, perceived stress has been previously reported to have a negative impact on diet quality in college students.[123] The most commonly observed impact of stress on diet quality is a reduction in fruit and vegetable intake.[154–157] Consumption of fast food items, or food high in added fat or sugar also increase directly with psychological stress.[133,156–158] Beyond diet quality, higher stress levels are associated with a reduction in eating competence, the practice of flexible and positive eating patterns that promote nourishment and enjoyability of food.[159]

While this study failed to report any significant associations between perceived psychological stress and diet quality, it does provide preliminary evidence for food security moderating the association between stress and diet quality, as measured by the HEI-2020 component scores for total vegetable and total protein intake. Surprisingly, among students experiencing food insecurity, elevated perceived stress was positively associated with compliance with the Dietary Guidelines for America for total protein intake. One study included in the systematic review by Shi et al[126] reported significantly more food insecure students purchasing less protein-rich foods, although that study did not contextualize the purchasing pattern in relation to overall diet quality, making it difficult to compare findings.[160] The current study found an opposite effect for total vegetable scores, where increasing perceived stress resulted in poorer compliance as a function of food insecurity. It is possible that the effect of food insecurity moderating total protein and PSS-10 scores could be explained by food insecure students' elevated intake of fast food, where many fast food locations offer low-cost, energy-dense options that provide large portions of animal proteins but little vegetables.[133]

This study adds to the limited literature that attempts to explore diet quality, stress, and food security in college students through a rigorous and validated approach to assess usual dietary intake among participants. Through repeated, interviewer-led, 24-hour recalls, we were able to reduce variance within student dietary records and increase the likelihood of a more complete record of daily intake that is reflective of students' usual dietary habits. By computing HEI-2020 scores, we conducted a thorough analysis that could pinpoint where and how participant diet quality was out of compliance with dietary guidelines. The students who participated were drawn from large and ethnically diverse universities, and despite low participation from Black and Native American students, the results are more generalizable among U.S. college students compared to previously published literature among more racial/ethnically homogenous cohorts.[126,161] This study used the PSS-10 which does not have the ability to characterize the specific nature or scenarios that produce of a person's stress, but it is one of the most widely used and validated measures of self-reported stress.[144] In spite of its racially diverse participant sample, the majority of the participants in this study were female, a feature common to many health-related studies, making it difficult to rule out the possibility of effects due to gender bias.[162]

In conclusion, findings from this study add to a limited body of evidence that diet quality among college students is suboptimal, thereby highlighting this population as a target for health behavior interventions. Although this study failed to report any significant associations for stress alone in predicting diet quality scores, food security was found to moderate the effect of stress on total vegetable and protein component scores for diet quality. Further research is required to understand if these findings can be replicated or if food security may exert stronger moderating effects among college populations with higher rates of food insecurity. Future studies to decipher the interactive effect of stress and food security on diet quality in college students should avoid convenience sampling techniques when gathering participant data, as this may fail to identify groups of students who have need. Furthermore, either data collection or analysis techniques should control for the time of year at which data is collected, given how this may affect reports of food security and stress levels among college students. Beyond food security, there may be other moderating factors that affect the relationship between stress and diet quality, such as racial group or age. The consideration of age as a risk factor for poor diet quality may also be addressed by more longitudinal studies that follow students for extended periods of time through their academic journey. Beyond addressing and resolving low food security, additional efforts will be needed to identify social and personal determinants of diet quality among college students.

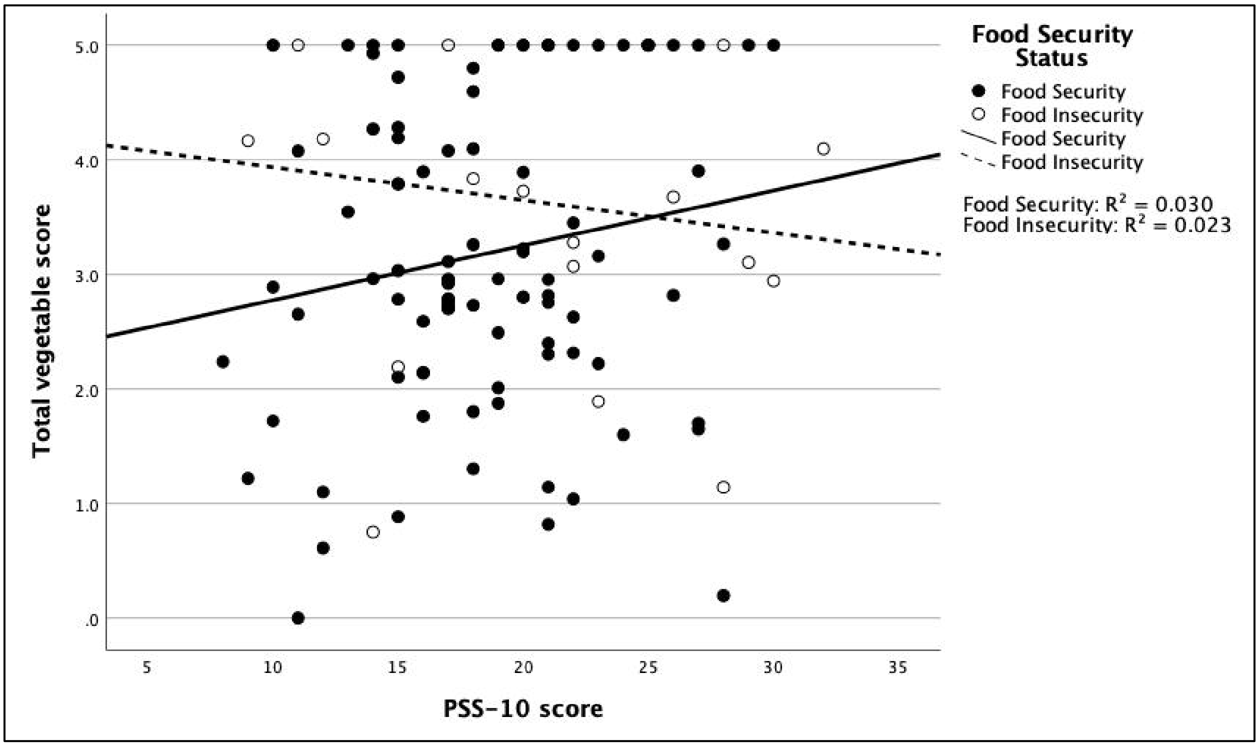

Figure 2.1 Association between perceived stress and Healthy Eating Index-2020 total vegetable score, as moderated by food security status. Abbreviations: PSS-10, Perceived Stress Scale 10-item.

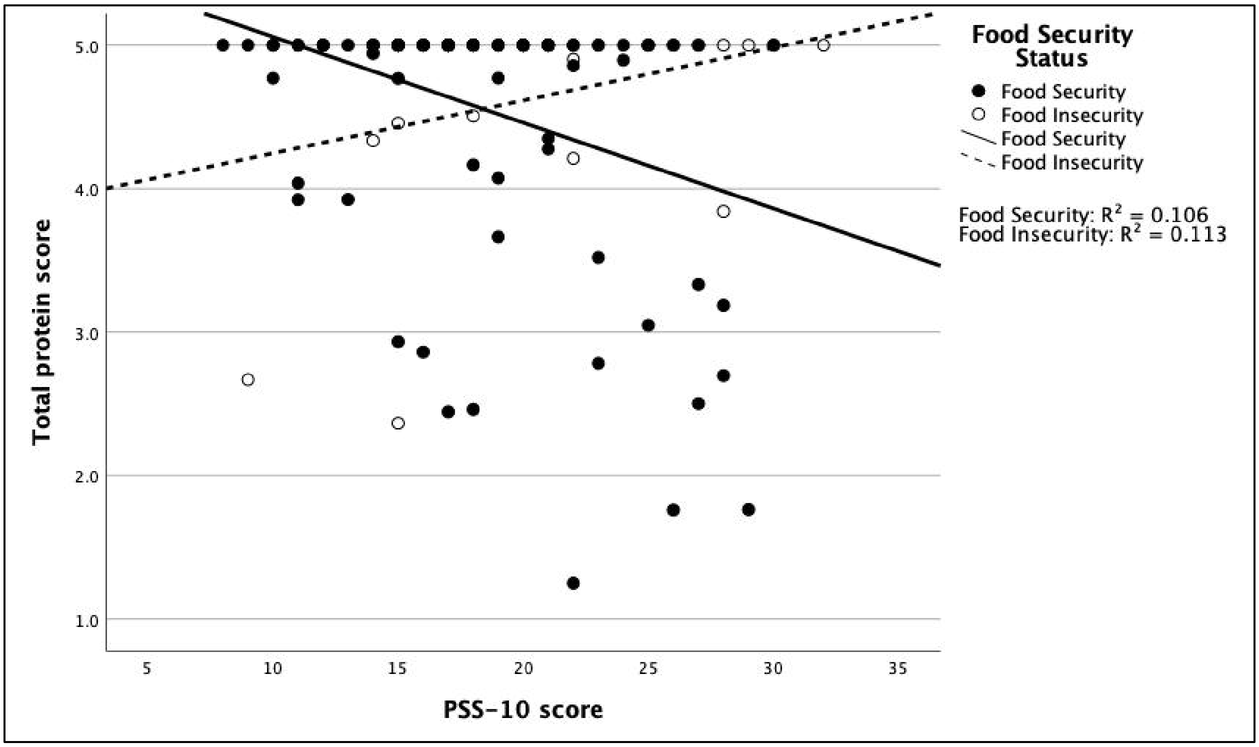

Figure 2.2 Association between perceived stress and Healthy Eating Index-2020 total protein score, as moderated by food security status. Abbreviation: PSS-10, Perceived Stress Scale 10-item.

TABLE 2.1: Baseline characteristics of study participants (n=114)

Demographic Variable	Mean (SD) or N (%)[1]	HEI-2020 Mean score (SD)
Age (years)	20.5 (1.8)	
PSS-10 score	19.0 (5.3)	
BMI (kg/m^2)	22.9 (4.1)	
Food Security Score	1.0 (1.8)	
Sex		
Male	20 (17.5)	53.7 (18.1)
Female	94 (82.5)	55.7 (12.8)
Race		
Black/African American	6 (5.3)	51.47 (21)
Other	15 (13.2)	56.9 (16.7)
White[2]	16 (14)	48.3 (13.2)
Hispanic/Latino	38 (33.3)	56.2 (13.5)
Asian/Asian American[2]	39 (34.2)	57.5 (11.3)
Residence		
Campus or university housing	35 (30.7)	55.8 (13)
Off-campus or temporary residence with relative, friend, or acquaintance	35 (30.7)	53.0 (14.7)
Parent/Guardian/Other family member's home	44 (38.6)	56.9 (13.6)
Food Security Status		
Food insecure	23 (20.2)	55.4 (12.3)
Food secure	91 (79.8)	55.3 (14.2)

SD, Standard Deviation; HEI 2020, Healthy Eating Index 2020; PSS-10, Perceived Stress Scale; BMI, Body Mass Index

[1]Continuous variables are presented as means and standard deviations, while categorical are presented as counts and percentage.

[2]Significant difference observed in HEI-2020 total score between racial groups at $p < 0.05$.

TABLE 2.2: Correlation coefficients for demographic variables in the study population (n=114)

Parametric Correlations (Pearson)

		HEI-2020 score	Food security score	PSS-10 score	Age	BMI
HEI-2020 score	r	1	--	--	--	--
	p-value					
Food security score	r	-0.001	1	--	--	--
	p-value	0.990				
PSS-10 score	r	0.013	0.224	1	--	--
	p-value	0.891	***0.017***			
Age	r	-0.123	0.336	-0.010	1	--
	p-value	0.194	***<0.001***	0.913		
BMI	r	-0.017	0.293	0.073	0.135	1
	p-value	0.854	***0.002***	0.442	0.152	

Nonparametric Correlations (Spearman's rho)

		HEI-2020 score	Sex	Race	Residence	--
HEI-2020 score	r	1	--	--	--	--
	p-value					
Sex	r	0.070	1	--	--	--
	p-value	0.459				
Race	r	-0.011	-0.087	1	--	--
	p-value	0.904	0.355			
Residence	r	-0.091	-0.059	0.040	1	--
	p-value	0.335	0.534	0.673		

HEI 2020, Healthy Eating Index 2020; PSS-10, Perceived Stress Scale; BMI, Body Mass Index

TABLE 2.3: Linear associations between perceived stress and HEI-2020 (n=114)

HEI-2020 Component	Unstandardized Coefficients		p-value	95.0% Confidence Interval for β	
	β	Std. Error		Lower Bound	Upper Bound
Total Fruit	0.013	0.033	0.698	-0.053	0.079
Whole Fruit	0.009	0.037	0.808	-0.064	0.082
Total Vegetable	0.027	0.024	0.255	-0.020	0.074
Green Beans	-0.007	0.036	0.840	-0.079	0.065
Total Protein	-0.028	0.015	0.065	-0.058	0.002
Seafood and Plant	0.053	0.037	0.148	-0.019	0.126
Whole Grain	-0.043	0.056	0.447	-0.153	0.068
Dairy	0.052	0.054	0.339	-0.055	0.158
Fatty Acid Ratio	0.012	0.062	0.850	-0.112	0.135
Refined Grains	0.049	0.063	0.440	-0.076	0.173
Sodium	0.000	0.053	0.995	-0.105	0.105
Sugar	-0.080	0.041	0.054	-0.161	0.001
Saturated Fatty Acids	-0.023	0.055	0.677	-0.133	0.086
HEI-2020 Total	0.034	0.244	0.891	-0.449	0.516

HEI-2020, Healthy Eating Index 2020

TABLE 2.4: Hierarchical regression analysis of perceived stress and food security status as predictors of HEI-2020 total and component scores, adjusting for covariates (n=114)

	Variables	Model 1					Model 2					Model 3				
		β	SE	95% CI (Lower/Upper)		P	β	SE	95% CI (Lower/Upper)		P	β	SE	95% CI (Lower/Upper)		P
HEI-2020 Total Score	Age (years)	-0.949	0.725	-2.386	0.488	0.193	-1.037	0.762	-2.546	0.473	0.176	-1.142	0.771	-2.670	0.386	0.141
	Race	0.247	0.862	-1.460	1.955	0.775	0.226	0.875	-1.508	1.961	0.797	0.151	0.880	-1.593	1.894	0.864
	BMI (kg/m^2)	-0.007	0.318	-0.637	0.623	0.983	-0.033	0.327	-0.681	0.614	0.919	0.030	0.334	-0.632	0.691	0.930
	PSS-10						0.012	0.250	-0.483	0.507	0.962	0.677	0.766	-0.842	2.197	0.379
	Food Security						1.482	3.504	-5.464	8.428	0.673	11.508	11.470	-11.230	34.246	0.318
	PSS-10 x Food Security											-0.507	0.552	-1.602	0.588	0.361
	R^2		0.016			0.63		0.02			0.86		0.03			0.84
Total Fruit Score	Age (years)	-0.086	0.098	-0.280	0.107	0.379	-0.069	0.102	-0.271	0.134	0.504	-0.081	0.104	-0.287	0.124	0.435
	Race	-0.067	0.116	-0.297	0.162	0.562	-0.073	0.118	-0.306	0.160	0.535	-0.082	0.118	-0.317	0.152	0.489
	BMI (kg/m^2)	-0.075	0.043	-0.160	0.010	0.082	-0.073	0.044	-0.160	0.014	0.100	-0.065	0.045	-0.154	0.024	0.149
	PSS-10						0.021	0.034	-0.045	0.088	0.525	0.100	0.103	-0.104	0.305	0.333
	Food Security						-0.256	0.471	-1.190	0.677	0.587	0.932	1.542	-2.125	3.990	0.547
	PSS-10 x Food Security											-0.060	0.074	-0.207	0.087	0.420
	R^2		0.044			0.178		0.049			0.356		0.055			0.406
Whole Fruit Score	Age (years)	-0.096	0.108	-0.311	0.119	0.378	-0.051	0.113	-0.275	0.173	0.653	-0.072	0.114	-0.297	0.154	0.530
	Race	-0.004	0.129	-0.260	0.251	0.972	-0.004	0.130	-0.261	0.253	0.974	-0.019	0.130	-0.277	0.238	0.883
	BMI (kg/m^2)	-0.089	0.048	-0.183	0.005	0.064	-0.078	0.048	-0.174	0.018	0.109	-0.066	0.049	-0.164	0.032	0.185
	PSS-10						0.019	0.037	-0.054	0.093	0.601	0.150	0.113	-0.074	0.375	0.187
	Food Security						-0.719	0.519	-1.748	0.310	0.169	1.256	1.694	-2.103	4.615	0.460
	PSS-10 x Food Security											-0.100	0.082	-0.262	0.062	0.224
	R^2		0.042			0.189		0.060			0.236		0.073			0.218

	Variables	Model 1					Model 2					Model 3				
		β	SE	95% CI (Lower/Upper)		P	β	SE	95% CI (Lower/Upper)		P	β	SE	95% CI (Lower/Upper)		P
Total Vegetable Score	Age (years)	-0.002	0.070	-0.141	0.137	0.981	-0.022	0.073	-0.166	0.122	0.762	-0.045	0.072	-0.189	0.099	0.536
	Race	-0.128	0.083	-0.293	0.037	0.128	-0.142	0.084	-0.308	0.023	0.091	-0.159	0.083	-0.323	0.005	0.057
	BMI (kg/m^2)	0.057	0.031	-0.004	0.118	0.065	0.048	0.031	-0.014	0.110	0.125	0.062	0.031	0.000	0.124	0.051
	PSS-10						0.026	0.024	-0.021	0.073	0.281	0.170	0.072	0.027	0.312	0.020
	Food Security						0.386	0.335	-0.277	1.050	0.251	2.556	1.077	0.420	4.692	0.019
	PSS-10 x Food Security											-0.110	0.052	-0.213	-0.007	***0.037***
	R^2	0.048				0.140	0.072				0.144	0.110				***0.049***
Green Beans Score	Age (years)	-0.029	0.108	-0.244	0.185	0.786	-0.083	0.113	-0.306	0.140	0.462	-0.111	0.113	-0.335	0.113	0.329
	Race	-0.128	0.129	-0.383	0.128	0.324	-0.133	0.129	-0.389	0.123	0.307	-0.152	0.129	-0.408	0.103	0.239
	BMI (kg/m^2)	0.027	0.048	-0.068	0.121	0.578	0.012	0.048	-0.083	0.108	0.797	0.029	0.049	-0.068	0.126	0.556
	PSS-10						-0.011	0.037	-0.084	0.062	0.758	0.162	0.112	-0.060	0.385	0.151
	Food Security						0.878	0.518	-0.148	1.904	0.093	3.495	1.680	0.164	6.825	0.040
	PSS-10 x Food Security											-0.132	0.081	-0.293	0.028	0.105
	R^2	0.012				0.716	0.038				0.516	0.061				0.329
Total Protein Score	Age (years)	0.028	0.045	-0.062	0.118	0.534	0.022	0.047	-0.071	0.115	0.640	0.041	0.046	-0.050	0.133	0.373
	Race	-0.080	0.054	-0.187	0.027	0.141	-0.069	0.054	-0.176	0.038	0.202	-0.056	0.053	-0.160	0.049	0.292
	BMI (kg/m^2)	0.026	0.020	-0.013	0.066	0.188	0.028	0.020	-0.012	0.068	0.168	0.016	0.020	-0.023	0.056	0.410
	PSS-10						-0.028	0.015	-0.059	0.003	0.072	-0.149	0.046	-0.240	-0.058	0.002
	Food Security						0.056	0.216	-0.372	0.485	0.796	-1.768	0.686	-3.127	-0.409	0.011
	PSS-10 x Food Security											0.092	0.033	0.027	0.158	***0.006***
	R^2	0.037				0.250	0.065				0.194	0.129				***0.020***

	Variables	Model 1					Model 2					Model 3				
		β	SE	95% CI (Lower/Upper)		P	β	SE	95% CI (Lower/Upper)		P	β	SE	95% CI (Lower/Upper)		P
Seafood and Plant Protein Score	Age (years)	0.054	0.110	-0.164	0.272	0.624	0.049	0.114	-0.178	0.276	0.669	0.057	0.116	-0.174	0.287	0.628
	Race	-0.112	0.131	-0.371	0.148	0.395	-0.136	0.132	-0.397	0.124	0.302	-0.131	0.133	-0.394	0.132	0.325
	BMI (kg/m^2)	0.005	0.048	-0.091	0.101	0.915	-0.003	0.049	-0.100	0.094	0.949	-0.008	0.050	-0.107	0.092	0.881
	PSS-10						0.057	0.038	-0.018	0.131	0.135	0.010	0.116	-0.219	0.239	0.934
	Food Security						0.182	0.527	-0.862	1.225	0.731	-0.526	1.729	-3.953	2.902	0.762
	PSS-10 x Food Security											0.036	0.083	-0.129	0.201	0.668
	R^2		0.008			0.827		0.031			0.636		0.032			0.732
Whole Grains Score	Age (years)	-0.208	0.166	-0.537	0.120	0.211	-0.152	0.172	-0.494	0.190	0.379	-0.143	0.175	-0.490	0.204	0.417
	Race	0.242	0.197	-0.149	0.633	0.222	0.271	0.198	-0.121	0.664	0.174	0.278	0.200	-0.118	0.674	0.167
	BMI (kg/m^2)	-0.008	0.073	-0.152	0.136	0.909	0.013	0.074	-0.133	0.160	0.858	0.008	0.076	-0.143	0.158	0.920
	PSS-10						-0.044	0.057	-0.156	0.068	0.436	-0.103	0.174	-0.448	0.242	0.554
	Food Security						-1.018	0.793	-2.591	0.554	0.202	-1.912	2.605	-7.075	3.252	0.465
	PSS-10 x Food Security											0.045	0.125	-0.203	0.294	0.719
	R^2		0.025			0.430		0.047			0.387		0.048			0.500
Dairy Score	Age (years)	0.094	0.160	-0.223	0.410	0.559	0.044	0.166	-0.285	0.374	0.790	0.019	0.168	-0.314	0.353	0.910
	Race	0.234	0.190	-0.142	0.610	0.219	0.210	0.191	-0.169	0.589	0.274	0.192	0.192	-0.188	0.573	0.319
	BMI (kg/m^2)	0.051	0.070	-0.087	0.190	0.464	0.033	0.071	-0.108	0.174	0.645	0.048	0.073	-0.096	0.192	0.511
	PSS-10						0.035	0.055	-0.073	0.144	0.516	0.195	0.167	-0.136	0.527	0.246
	Food Security						0.884	0.765	-0.633	2.401	0.251	3.292	2.503	-1.670	8.255	0.191
	PSS-10 x Food Security											-0.122	0.121	-0.361	0.117	0.315
	R^2		0.026			0.412		0.043			0.442		0.052			0.445

	Variables	Model 1					Model 2					Model 3				
		β	SE	95% CI (Lower/Upper)		P	β	SE	95% CI (Lower/Upper)		P	β	SE	95% CI (Lower/Upper)		P
Fatty Acid Score	Age (years)	-0.510	0.180	-0.867	-0.152	0.006	-0.522	0.189	-0.897	-0.146	0.007	-0.545	0.192	-0.926	-0.165	0.005
	Race	0.056	0.214	-0.368	0.481	0.793	0.052	0.218	-0.379	0.484	0.811	0.036	0.219	-0.399	0.470	0.871
	BMI (kg/m^2)	0.042	0.079	-0.114	0.199	0.595	0.038	0.081	-0.123	0.199	0.640	0.052	0.083	-0.113	0.217	0.533
	PSS-10						0.004	0.062	-0.119	0.127	0.945	0.152	0.191	-0.227	0.530	0.429
	Food Security						0.211	0.872	-1.517	1.939	0.809	2.430	2.856	-3.230	8.091	0.397
	PSS-10 x Food Security											-0.112	0.138	-0.385	0.160	0.416
	R^2		0.068			0.051		0.069			0.169		0.074			0.209
Refined Grains Score	Age (years)	0.281	0.187	-0.089	0.652	0.135	0.195	0.193	-0.188	0.578	0.316	0.163	0.195	-0.224	0.551	0.405
	Race	0.014	0.222	-0.426	0.454	0.949	-0.018	0.222	-0.458	0.423	0.937	-0.040	0.223	-0.482	0.402	0.857
	BMI (kg/m^2)	0.029	0.082	-0.133	0.192	0.721	<0.001	0.083	-0.164	0.164	1.000	0.019	0.085	-0.149	0.187	0.824
	PSS-10						0.037	0.063	-0.088	0.163	0.558	0.236	0.194	-0.149	0.622	0.226
	Food Security						1.508	0.890	-0.256	3.272	0.093	4.509	2.908	-1.256	10.273	0.124
	PSS-10 x Food Security											-0.152	0.140	-0.429	0.126	0.281
	R^2		0.024			0.451		0.054			0.299		0.064			0.300
Sodium Score	Age (years)	-0.146	0.155	-0.453	0.161	0.349	-0.133	0.163	-0.456	0.190	0.415	-0.136	0.165	-0.464	0.192	0.414
	Race	0.402	0.184	0.037	0.767	0.031	0.408	0.187	0.038	0.779	0.031	0.406	0.189	0.032	0.781	0.034
	BMI (kg/m^2)	-0.052	0.068	-0.187	0.082	0.442	-0.048	0.070	-0.186	0.091	0.495	-0.046	0.072	-0.188	0.096	0.520
	PSS-10						-0.009	0.053	-0.115	0.097	0.868	0.008	0.164	-0.318	0.334	0.962
	Food Security						-0.225	0.749	-1.709	1.260	0.765	0.027	2.461	-4.852	4.906	0.991
	PSS-10 x Food Security											-0.013	0.119	-0.248	0.222	0.915
	R^2		0.050			0.128		0.051			0.329		0.051			0.451

	Variables	Model 1					Model 2					Model 3				
		β	SE	95% CI (Lower/Upper)		P	β	SE	95% CI (Lower/Upper)		P	β	SE	95% CI (Lower/Upper)		P
Sugar Score	Age (years)	0.055	0.124	-0.192	0.301	0.662	0.021	0.129	-0.234	0.276	0.873	0.050	0.129	-0.206	0.307	0.697
	Race	-0.138	0.148	-0.431	0.156	0.354	-0.111	0.148	-0.404	0.182	0.454	-0.090	0.147	-0.382	0.203	0.544
	BMI (kg/m ^{2})	-0.033	0.055	-0.141	0.075	0.549	-0.033	0.055	-0.142	0.076	0.549	-0.051	0.056	-0.162	0.060	0.365
	PSS-10						-0.078	0.042	-0.162	0.006	0.067	-0.266	0.129	-0.521	-0.011	0.041
	Food Security						0.432	0.592	-0.741	1.606	0.466	-2.398	1.923	-6.210	1.415	0.215
	PSS-10 x Food Security											0.143	0.093	-0.040	0.327	0.125
	R^2		0.012			0.722		0.045			0.414		0.066			0.285
Saturated Fatty Acid Score	Age (years)	-0.384	0.161	-0.704	-0.064	0.019	-0.336	0.169	-0.670	-0.001	0.049	-0.340	0.171	-0.680	-0.001	0.050
	Race	-0.045	0.192	-0.426	0.335	0.814	-0.029	0.194	-0.413	0.355	0.882	-0.032	0.196	-0.420	0.355	0.870
	BMI (kg/m ^{2})	0.013	0.071	-0.128	0.153	0.859	0.029	0.072	-0.115	0.172	0.693	0.031	0.074	-0.116	0.179	0.672
	PSS-10						-0.018	0.055	-0.127	0.092	0.747	0.012	0.170	-0.326	0.350	0.944
	Food Security						-0.837	0.776	-2.375	0.702	0.283	-0.386	2.550	-5.440	4.668	0.880
	PSS-10 x Food Security											-0.023	0.123	-0.266	0.221	0.853
	R^2		0.051			0.120		0.063			0.210		0.064			0.307

SE, Standard Error; CI, Confidence Interval; HEI-2020, Healthy Eating Index 2020; BMI, Body Mass Index; PSS-10, Perceived Stress Scale

RESEARCH CHAPTER 3: A Simple, Personalized Intervention to Improve Diet Quality in Full Time College Students

INTRODUCTION

College life is a significant milestone in the lives of young adults when they must learn to navigate newly expanded autonomy, develop a sense of self-identity, and shoulder new responsibilities for managing and maintaining their health.[26] Diet plays a significant role in the maintenance of health and prevention of chronic illness, and the dietary intake of college students can be influenced by preferences, food access, personal knowledge of health, level of motivation, and psychological stress.[121–123] Despite these potential challenges, college should be considered an appropriate context for improving the diet quality of young adults. Whether there is less reliance on previous support systems, a desire to foster an identity rooted in care for self, or a realization that new freedoms have brought new responsibilities, circumstances can provide motivation for change in college students who want to improve their diets, if simply given a prompt.[25–27]

While college years are an ideal time period for health interventions, college students may struggle to convert general counsel into actionable dietary behaviors that suit their circumstances, as evidenced by limited finances, lack of interest, incorrect perceptions about food and diet, perceptions of general ability to make changes, and other similar barriers.[30–33] Many interventions that aim to modify students' diets are designed as classes or programs, which recruit and instruct college students with varying levels of success for dietary outcomes.[34] However, students frequently report struggles with academic stress and time management, so asking them to enroll in an additional class or program may not be a feasible method for diet modification.[163] This prompts questions about alternative approaches to modifying diet which consider the various inputs that produce those dietary choices in the first place.

Dietary patterns result from a complex web of behavioral, intrapersonal, and environmental influences, and in an effort to maximize intervention effects, researchers look to environmental and structural factors to improve diet, such as food taxes which discourage purchase of certain items.[164] Such broad interventions have capacity to impact large numbers of participants who inhabit a similar environment, but consequential of this blanketed coverage, structural interventions do not consider individual circumstances and can have unintended effects if not crafted with precision.[71] In contrast to structural changes to the food environment, interventions may be tailored to target smaller groups and consider more personalized circumstances, ultimately modifying a component or whole of a person's diet.

There is evidence to suggest that simple interventions can be crafted to consider environmental constraints and successfully improve dietary behavior.[56] These interventions focus on behavior change and can be tailored to suit unique needs by tapping into intrinsic motivation, and enhancing autonomy, effort, and perceived self-efficacy.[70] Broad, structural modifications simply cannot account for the unique circumstances, beliefs, or values of individuals, and interventions tailored to individuals are demonstrably more successful than generic dietary recommendations.[165–168]

Theoretical Framework for the Current Study

The Social Cognitive Theory (SCT) posits that, when suggested behaviors are simple, easy to understand, and relatable, individuals are more likely to practice such behaviors, increasing the likelihood of long-term behavior change.[108,109,169] The framework for the current study's design was influenced by SCT and findings from a systematic review examining outcomes of studies that employed easy-to-learn interventions meant to improve diet quality in young adults.[170] SCT attempts to explain human behavior through a reciprocal causation model, wherein the interactions of our behaviors, personal factors, and environment can each exert influence on one another.[66] When behaviors are perceived as simple, easy to understand, and relatable, individuals are more likely to practice them, thus increasing the likelihood of long-term behavior change.[108,109,169] Through individualized efforts, participants may become more aware of their environmental surroundings and make modifications that facilitate the desired behavioral outcomes.[109] Though the effects are modest, there is significant improvement to diet quality through interventions that have participants write out or articulate a simple dietary change intention, and then actively remind themselves of the stated intention.[170]

College students may not suffer immediately from poor dietary choices, or be diagnosed with diet-related chronic diseases, but a body of recent evidence demonstrates that their diet quality falls far short of meeting a diet recommended for health maintenance and disease prevention.[40,78–80,171] Among the limited dietary interventions aimed at college students, many are designed as either structural modifications or health-related classes and programs that place additional time constraints on students who already deal with various academic demands.[34,84] Alternative approaches to improving health are needed, where the total perceived cost of engagement is minimal and perceived control is amplified by giving participants options on what they would like to improve. The aim of this intervention study was to investigate whether or not a simple and individually modifiable diet behavior change intervention could improve diet quality among a sample of college students from two large university campuses, compared to a passive control group. This intervention provided a consistent reminder of dietary practices selected at the discretion of the participant, and required no demands upon the participants' time beyond required data collection. Participants' readiness for behavior change was assessed as a potential modifier of the effect of the intervention on the dietary outcome. A secondary aim was to evaluate the feasibility and participant acceptability of the intervention.

METHODOLOGY

This study was a single-blinded, two-armed, individually randomized controlled trial (RCT) approved by the IRB from UC Irvine, where all participants provided consent (trial registration: ISRCTN 53920728).

Power Analysis

HEI-2020 total score was the primary outcome of interest. Using data on the variation in HEI scores from a previous study in a college population,[172] power analysis determined that 102 participants would be needed for the current study to have 90% power to detect a 6 point difference between groups in HEI-2020 at follow-up.

Participants

Participants were recruited from August 2022 to March 2023 from two universities in Southern California with large and ethnically diverse student populations. Recruitment was conducted through mass email blasts within departments, announcements in general elective courses, flyers posted on campus, and word of mouth referral from any who participated. Eligibility criteria for participation were age 18 to 25 years, enrolled full time as a student at their university, fluent in English, without medical conditions or allergies that would require modification of diet, without eating disorder symptoms, and with a diet not currently complying with dietary guidelines.

For pre-screening purposes, interested students completed online surveys through the Research Electronic Data Capture system (REDCap) so that the research team could determine eligibility. This included i) the SCOFF questionnaire which is considered an effective screening instrument for detecting eating disorders, asking the participants five yes-or-no questions, where two or more answers for "yes" on any question indicate a likely case of having an eating disorder,[119,120,137] and ii) a 7-item diet screener survey adapted from the Rapid Eating and Activity Assessment for Patients Short version (REAP-S), a validated survey that can accurately assess food group servings which characterize a healthy diet.[138] Scores ranged from 7 to 21, and students who scored higher than 18 on the diet screener were likely consuming a diet with high compliance to dietary guidelines, and thus excluded from participation, allowing for participation from students more likely to benefit from the study intervention, while also reducing bias from social desirability.[139] If eligible after completing this screening survey, participants were provided additional study information, invited to consent to participating in the study, and if agreeing to participate, asked to provide their best contact information.

Procedure

Baseline Data Collection

Upon enrollment, participants were sent an introductory email providing them with a unique four-digit code for REDCap record identification, a secure REDCap link to their baseline surveys (see Measures section below), and requesting best times of day to contact for follow-up study procedures. They were then contacted by phone on random days and asked to complete two separate interviewer-led, 24-hour recalls using the Automated Self-Administered 24-hour recall tool (ASA24), a validated, free web-based program offered by the National Cancer Institute (NCI).[140] Completion of two diet recalls on non-consecutive days follows best practices to reduce risk of outliers and minimize within-participant variance in dietary data.[141] Participants were contacted through calls and texts to initiate and assure collection of baseline data. If participants were nonresponsive to communications after two weeks, they were dropped from the study.

Randomization and Blinding

Allocation to the control or experimental group was determined through individual randomization in a 1:1 ratio using the NCI's Clinical Trial Randomization Tool.[173] The randomization sequence generated by the tool was stored electronically by the lead investigator and only revealed sequentially to participants and research personnel once each participant completed baseline data collection. Due to the nature of the behavioral intervention, neither participants nor research personnel were blinded to group allocation.

Follow-up Data Collection

At week 4, exactly 28 days after confirmation of intervention receipt, the research team initiated contact with all study participants and invited them to complete two additional diet recall surveys, led by the interviewer on ASA24, on non-consecutive and randomly chosen days. At week 8, exactly 28 days after completing the second recall of week 4, participants were invited to complete two final diet recalls according to the same format as baseline and week 4, along with a feasibility questionnaire and post-study surveys on REDCap to assess perceived stress and readiness to change. Participants were compensated with cash at each timepoint after completion of all baseline ($10), week 4 ($15), and week 8 ($20) surveys and diet recalls.

Intervention

Once the second baseline diet recall was completed, participants in the experimental group were shown the list of seven dietary change statements, asked to read through the list, and select the two statements they would be most interested in fulfilling. Four statements were standardized, three allowed minor personalization according to the student's preferences, and each was meant to improve at least one facet of the student's diet quality, which represented the primary outcome measure. Any allowable personalization to selected tags were recorded within the selected tags before being printed and laminated. The participant and researcher agreed upon a mutual time and location for delivery of the tags. Upon delivery, participants were instructed to attach the tags to their keys, or smartphone if keys were not an option, and carry them on their person wherever they went for the next 4 weeks. Participants were then informed they would be contacted again to complete additional 24-hour recalls in the future, and to contact the research team should the tags be lost or damaged.

Control

Similar to participants in the experimental group, participants in the control group were provided with their assigned treatment after completion of the second baseline 24-hour recall. Participants were given a brief description of the Dietary Guidelines for Americans (DGAs) and asked to read through at least the executive summary, and consider the DGAs principles in relation to their diet, but no additional directives were given. A link to the most recent DGAs was then emailed and texted to the participant, with a follow-up summary of instructions to read and consider the principles. Similar to the experimental group, participants were informed they would be contacted again to complete additional 24-hour recalls.

Measures

Participant Demographics

Baseline demographic data collected included age, sex, self-reported weight and height, major of study, residency status, and race. Age was measured by number of years. Sex was recorded by sex assigned at birth, with three response options including "Male", "Female" and "Intersex", the latter referring to individuals who were born with any variation in sex characteristics not typical of males or females, due to chromosomal or gonad alterations.[142] Weight and height were self-reported and recorded in pounds and inches. Major of study was the students' current declared major. Residency was captured from a list of options designating the students' current living situation. Lastly, self-identified race was reported as either, "Asian or Asian American", "Black or African American", "Hispanic or Latino", "White", "American Indian or Native Alaskan", "Middle Eastern/North African or Arab Origin", "Native Hawaiian or Other Pacific Islander Native" or "Biracial or Multiracial". Given the limited number of responses on the latter four racial categories, these were compiled together and labeled as "Other".

Primary Outcome: Healthy Eating Index-2020

The 2020 Healthy Eating Index (HEI-2020) is a measure of overall diet quality, and used to assess how well an intake pattern aligns with key recommendations for the DGAs.[40,143] The HEI-2020 is a composite score made up of 13 components, nine of which promote dietary adequacy, while four focus on limiting intake of foods that contribute saturated fats, refined grains, added sugars, and sodium. The sum total of these components provides an indication of diet quality, scored from 0 to 100, with a higher score interpreted as better diet quality. Information collected from ASA24 recalls was linked to intake data through the 2017-2018 Food and Nutrient Database for Dietary Studies, allowing for subsequent calculation of HEI-2020 scores. The HEI-2020 was computed from diet recall data at baseline, week 4 and week 8 of the trial, as described below under Statistical Analysis.

Secondary Outcome/Moderator: University of Rhode Island Change Assessment Scale

Data on participant readiness to change was collected using the University of Rhode Island Change Assessment Scale (URICA). The scale is a validated 32-item, 5-point Likert scale questionnaire designed to provide continuous measure of a subject's willingness to change, based on the transtheoretical model of behavior change, and is frequently used in assisting healthcare professionals with behavioral assessment with health-related behaviors.[174,175] For the general population, a score of ≤8 is classified as Precontemplation, 8-11 as Contemplation, and >11 is Preparation or Action.[176] Readiness to change was assessed at baseline (preURICA) and week 8 (postURICA) of the study.

Perceived Stress Scale

Perceived stress of participants was determined using the Perceived Stress Scale-10 (PSS-10), a 10-item questionnaire that asks questions about perceptions of stressful experiences in the past month, answered and scored from 0 to 40, with a higher score indicating higher stress levels. The PSS-10 has been consistently reported to be a valid and reliable indicator of perceived stress in adult populations.[144]

Food Security

Food security was assessed using the USDA-ERS's Food Security 6-item short form, where a higher score indicates lower food security (score range: 0-6).[145] A score ≥2 on the survey was designated as experiencing food insecurity, while a score 0-1 was categorized as experiencing food security.

Statistical analysis

Baseline Descriptives

Survey data were assessed for completion of all questions, with duplicate or incomplete records (presented an ID number, but were missing the minimum demographic data or did not show record of completed 24-hour recalls) being removed. If a participant failed to complete the two baseline 24-hour recalls after numerous contact attempts, they were coded as a drop-out from the study. Survey data was collected through REDCap, a web-based survey and data management application hosted by the university, while ASA24 was used to collect dietary data through 24 hour-recalls, and records within both platforms were matched using a unique four-digit code ID assigned to students at the start of the study. Once records were matched, diet recall data was reviewed for outliers or incomplete information. Records were excluded from analysis if they reported extremely low mean daily calorie intake (<600 kcals for women; <650 kcals for men) that indicated likely underreporting and thus, unreliable data.

Baseline characteristics were depicted as means and standard deviations or as medians and interquartile ranges for continuous variables, and as percentage and number of students for categorical variables. Chi-square tests were conducted for calculating group difference by sex, residence, and food security status, and Fishers exact test for race. Independent sample t-tests were conducted for group differences by preURICA, PSS-10, and baseline HEI-2020 scores, and Mann Whitney U tests for age and BMI since data were not normally distributed.

Primary Outcome Analysis

For the primary analysis, HEI-2020 scores were calculated as recommended using the population ratio method.[177] This method computes scores based on the ratio of average component intake to average energy intake for all people within a subpopulation of interest (i.e., an intervention or a control group), wherein the scoring algorithm is then applied to produce HEI-2020 component and total scores for that subpopulation. Using these ratios, HEI-2020 scores were calculated for both groups, at all three timepoints, for a total of six separate group-level scores. This method is shown to reduce bias when compared to alternative methods for calculating HEI-2020 scores.[177] Next, a macro code provided by NCI was used to run a Monte Carlo simulation step for the calculation of standard errors and confidence intervals (CI).[178] At the time of this study, there is no direct statistical test for analyzing differences between groups when using the population ratio method, therefore, comparisons are made using the calculated 95% CIs. As determined in previous work, if CIs overlapped between two subpopulations (within or between groups at each timepoint), it was concluded that the difference was not significant.[179] If CIs did not overlap, it was concluded that a significant difference in the HEI-2020 score did exist. Given that p-values were not generated by this method, it was not possible to correct for multiple testing.

An intent-to-treat (ITT) analysis was conducted using multiple imputation to generate nutrient and food intake datapoints at follow-up time points for all participants who were dropped or withdrew before completing the study. Using this complete dataset, the HEI-2020 total and component scores were recomputed using the population ratio method and the results were compared to those of the original scores (i.e., before multiple imputation).

Repeated Measures Analysis

Since the population ratio method generates a single HEI-2020 value per subpopulation in a study, it cannot accommodate covariates or other predictors in analytic models. Therefore, HEI-2020 was also computed using the simple scoring method which generates HEI-2020 values at the participant level at each timepoint of diet assessment. This method is carried out for each participant, and involves aggregating the relevant dietary constituents into their HEI-2020 component groups. Ratios are then constructed for each of the components, most being calculated for every 1,000 calories consumed by the participant, with the exception of fatty acids. Fatty acid ratios are the sum of monounsaturated and polyunsaturated fatty acids to saturated fatty acids. Ratios are then scored according to HEI scoring standards set for each component, with the sum of each participant's components scores providing the total HEI-2020 score. Using these individual-level HEI-2020 scores, we conducted a two-way repeated measures ANOVA to assess change in HEI-2020 total and component scores across time and between groups. Though this approach is not validated for comparing HEI-2020 scores across intervention and control groups in a randomized trial, it provides the best available current method of including covariates in the analysis, which included BMI, age, race, and preURICA scores. Timepoints for baseline, week 4, and week 8 were selected as the within-subjects factor. Group assignment was designated as the between-subjects factor, with age, race, and BMI entered as covariates. Perceived stress and food security were not included as covariates given previous analyses that indicated neither variable had a significant association with HEI-2020 total scores (please refer to Chapter 2). Correction for multiple testing using the False Discovery Rate method was considered for the 14 separate tests of between-group changes across study timepoints in HEI-2020 total and component scores.[180]

To test the effect of group assignment on participants' readiness to change, a two-way repeated measures ANOVA was conducted for the change in continuously measured URICA scores between groups. Additionally, to explore the relationship between participant readiness to change and diet quality, correlations for preURICA and postURICA scores, and participant-level HEI-2020 total and components scores at each timepoint were conducted using Pearson's test. Additionally, to explore whether or not tag selection led to dietary improvements specific to its related HEI-2020 component score within the intervention group (e.g., did selection of the tag related to fruit intake affect total and/or whole fruit intake), or to improvement in an unrelated dietary component, repeated measures analysis was conducted stratified by the most commonly selected tags to examine change in the HEI-2020 component scores across time.

Hierarchical Multiple Regression Analysis

Hierarchical multiple linear regression was conducted first to test the main effects of preURICA scores and group assignment, as well as the interaction effects of preURICA scores x group assignment, on HEI-2020 total and component scores at weeks 4 and 8 as the outcome measures. Age, BMI, and race were included as *a priori* covariates for model one, preURICA score and group assignment were entered in model two, and interaction of preURICA score x group assignment entered in model three. To determine the effect of change in URICA score over the course of the study on HEI-2020 and component scores at week 8, a second hierarchical regression analysis was conducted that included the same *a priori* covariates for model one, preURICA score, change in URICA score, and group assignment for model two, and interaction of change in URICA score x group assignment for model three.

Feasibility survey data analysis

Finally, responses to the Likert-scale questions in the feasibility survey were described using bar charts. Open-ended responses from both the control and experimental group were read, with response examples selected that were representative of diverse opinions within both groups.

Statistical analyses were performed using the software *Statistical Analysis System* (SAS) version 9.4 for Windows for the primary analysis using the population ratio method. The *Statistical Package for the Social Sciences* (SPSS) version 29 for Windows was used for all other analyses. P-values < 0.05 were considered statistically significant.

RESULTS

Baseline Demographics

Screening and enrollment numbers are reported in Figure 3.1, with 61 and 53 students assigned to the control and experimental groups at baseline, respectively. Descriptive characteristics for each study group are reported in Table 3.1, with no statistically significant differences between groups at baseline. The median age of students was 20.0±2.0 years, with a median BMI of 22.6±4.3 kg/m^2. The majority of the students were female (82.5%) and there was broad diversity in self-identified racial groups. Baseline URICA scores ranged from 2.7 to 12.1, with a mean score of 8.3 which is interpreted as being in a stage of Contemplation, according to the Transtheoretical Model of Behavior Change.[175] A total of 36 different majors of study were reflected in student survey responses. The majority were public health majors (n=19), followed by nutrition and dietetics (n=10), then business (n=9), with a diverse array of majors thereafter, among which included acting, fashion, and speech language pathology.

Absolute counts for each tag selected are reported in Table 3.2, along with the exact text associated for each tag. The most commonly selected tags were those that promoted fruit (n=28) and vegetable (n=26) intake. The least commonly selected tags were those that promoted dairy (n=5) and discouraged consumption of fried and processed meats (n=5).

Primary Outcome

Main results for the primary outcome of difference in HEI-2020 total score between groups across time points are reported in Figure 3.2 and Table 3.3. The intervention revealed no significant changes between or within groups at any time for the HEI-2020 total score. However, in observing non-significant changes in HEI-2020 scores within groups, it was seen that the control group began at 62.2, increased to 65.5 at week 4, and returned to 62.9 by week 8. In contrast, though also non-significant, the experimental group's HEI-2020 score showed small increments at each time point, from 60.1, to 61.9, to 63.4. Among the HEI-2020 component scores, the only significant change detected was the control group's total vegetable score which increased from baseline to week 4, and returned to baseline levels by week 8 (although the difference in this score between groups was not significant at either time point) (Table 3.3). The experimental group had a higher dairy component score compared to the control at week 4 which approached significance (Control Upper CI = 5.98, Experimental Lower CI = 5.61). The total protein score was maxed at 5 for both groups at every time point, thus not allowing for any significant improvements within or across groups. All other scores varied between their maximum and minimum scores. The lowest diet component scores reported were for sodium, where a maximum score of 10 could be achieved, and the control and experimental groups' scores at each timepoint were respectively 2.3, 2.1, 2.5, and 0.6, 1.6, 1.5. The ITT analysis results are also reported in Appendix Table 1, which demonstrate consistent results for HEI-2020 total score and component scores compared to the per-protocol analysis as described above.

Repeated Measures Analysis

Results of a two-way repeated measures analysis with the participant-level HEI-2020 scores and adjustment for covariates reported no significant difference in HEI-2020 total or components scores between groups or across time points, which is consistent with the results of the population ratio method (see Appendix Table 2). Given no significant results at $p<0.05$ were detected, correction for multiple testing was not conducted. Meanwhile, participants' readiness to change scores were found to significantly differ across timepoints but not between groups, such that the mean preURICA score for the whole sample was 8.3±1.7 and the mean postURICA score was 8.5±1.6 ($p=0.041$, see Appendix Figure 1).

Results of the repeated measures analysis conducted within the experimental group for the most commonly selected tags (consumption of whole grains, fruits, vegetables, and reduction of sugar-sweetened beverages [SSB]) and all diet components as outcome measures are reported in Appendix Figures 2 and 3. Post hoc analysis reported a significant difference between time points for the sugar component score when the fruit tag was selected (F=5.019, p=0.013), with compliance to the dietary guidelines for sugar intake increasing from baseline to week 4 (Mean difference=1.48, p=0.031). There was also a significant change noted in the whole fruit component score when the whole grains tag was selected (F=4.385, p=0.031), such that the post hoc analysis indicated decreasing compliance to the dietary guidelines for whole fruit intake from baseline to week 8 (Mean difference=-1.55, p=0.061).

Correlation Coefficients

Results of the Pearson's correlation test using the participant-level HEI-2020 scores are reported in Table 3.4. There was a significant correlation for the week 4 sodium component score with preURICA scores (r=0.287; p=0.003). There were no other significant associations for HEI-2020 total or component scores at baseline, week 4, or week 8 with preURICA and change in URICA scores.

Hierarchical Regression Results

Hierarchical regression analysis for the main effects of preURICA scores and group assignment, as well as the interaction effects of preURICA score x group assignment, on individual-level HEI-2020 total and component scores for week 4 are reported in Table 3.5. There was a significant main effect of preURICA score on the refined grains component (β = 0.575, CI = 0.122, 1.028, p = 0.013) such that higher preURICA scores were associated with higher compliance with dietary guidelines for refined grains intake, and models two and three significantly explained 11.8% and 12% of the variance, respectively. Models two and three for the sodium component score were significant, explaining 13.9% and 14.1% of the variance, respectively, though only the covariates age and race had a significant main effect. There was a significant interaction effect of preURICA x group assignment on the sugar component score ($\beta = -0.516$, CI = -0.963, -0.068, $p = 0.024$). A scatterplot subdivided by group assignment demonstrated that for the control group, increasing baseline readiness to change scores corresponded with improved compliance with dietary guidelines for sugar intake, while the opposite association was observed for the experimental group (Figure 3.3). Models two and three for the saturated fatty acid component score were significant, both explaining 16.1% of the variance, but age was the only covariate that had a significant main effect. Results of the similar analysis for week 8 reported no significant main or interactive effects on HEI-2020 total or component scores, and are detailed in Appendix Table 3.

Hierarchical multiple regression results with change in URICA score as a predictor variable and week 8 HEI-2020 and component scores as the outcome variables are reported in Table 3.6. There was a significant main effect for group assignment on the green and beans component score ($\beta = 0.897$, CI = 0.018, 1.777, $p = 0.035$) as well as a positive association between the change in URICA score and the sugar component score ($\beta = 0.469$, CI = 0.059, 0.879, $p = 0.025$).

Feasibility Survey Results

Results from the feasibility survey are reported in Figure 3.4. There were 39 completed surveys from students in the experimental group, while 14 students either withdrew before study completion or submitted incomplete surveys. Responses to the first six questions about student perception of the intervention's ease, usefulness, efficacy, and likelihood of maintaining the practices after study termination were generally favorable, with those who agreed or strongly agreed ranging from 66.7% to 84%. The final question addressed whether or not practicing the selected dietary behaviors felt burdensome or time-consuming, with 61.5% disagreeing or strongly disagreeing. Students offered positive written feedback regarding their experience. Many said the intervention was helpful and constantly reminded them of their diet. Selected quotes from these responses include: *"This study really helped me with my dietary behaviors and I found myself self-motivated to incorporate fruit and water into my diet…"; "I was constantly reminded of the study, which was good in reminding me of the dietary habits I chose to follow."*; "*It has now become second nature for me to eat fruit and drink water. I love the fact that I was able to pick up the good habit."* Others expressed difficulty with making changes: *"I felt like my goals were unrealistic like vegetables at breakfast and I really tried and it became hard…"; "Initially I tried to follow the cards, but it was difficult to implement each specific diet in everyday meals."* Surprisingly, there were also many positive comments offered regarding the control group's treatment: *"…I felt that reading the Executive Summary of the Dietary Guidelines for Americans made me more aware of what I am eating…"; "I was able to reflect on my eating habits during the recalls."; "I really enjoyed this study because it made me notice what kinds of foods I was eating…"*

DISCUSSION

Primary Outcomes

This randomized controlled trial successfully assigned a diverse group of college students to follow a simple intervention that prompted them to modify selected dietary behaviors they had personally chosen, while the control group was provided with and asked to read the most recent DGAs. Contrary to expectations, there were no significant changes to HEI-2020 or its component scores between or within the control and experimental groups when analyzing the data using the recommended population ratio method. At week 8, HEI-2020 scores were 62.9 for the control group, and 63.4 for the experimental group, both of which are lower than the nationwide mean of 64.8±0.2 and well below the recommended score of 80.[40,41] The only significant change was the control group's total vegetable score increase from baseline to week 4. These results are contrary to findings from previous studies among young adults that reported significant improvement in at least one aspect of diet quality following a simple intervention prescribing small dietary changes or carrying a prompt as a daily nudge to promote dietary change.[56,98–100] However, there were interesting observations from the reported scores across groups.

Three component scores that merit analysis from the main outcome results are sodium, total protein, and seafood and plant protein. Among all 13 dietary components of the HEI-2020, the sodium component reported the lowest scores, as a function of points possible, indicating poor compliance with dietary guidelines to limit sodium intake. There are surprisingly few studies that attempt to specifically measure sodium intake using either HEI or the DGAs as a standard, and even fewer which do so among American college students. One study assessed the sodium intake of college freshmen, reporting that just over 50% met the 2015-2020 DGA standard of consuming no more than 2,300 mg/day.[181] The highest reported sodium component score for the current study was the control group at week 8, at 2.53 out of 10, which computes to an average intake of 3,337 milligrams. Given these findings, it is possible that sodium intake may be greater on college campuses than previously thought, a problem considering sodium intake's relationship to high blood pressure and chronic illness.[182,183] College students often have access to and select highly processed convenience foods that offer energy-dense options along with animal proteins, all of which are typically very high in sodium content. Although intake of highly processed foods and animal proteins was not directly evaluated in this study, it can be speculated that such diet patterns could help explain the perfect total protein scores reported across all time points for both groups.[33,133,184] Somewhat contrary to the above speculation, intakes of seafood and plant proteins were also consistently high, near perfect for both groups at weeks 4 and 8. One possible explanation for these results is the connection between college students and environmentally conscious attitudes, particularly those that associate food choices with environmental impacts. Nationally representative surveys report 85% of college students believing it to be at least be somewhat important that their college campus prioritize sustainability, and are more likely to select plant-based protein options compared to older individuals or less educated peers.[185–187] Other possible explanations for the higher plant and seafood protein score include the ethnic diversity of participants such that these food selections may be culturally preferred, or, the lower cost of plant-based protein foods.

Though not validated for this data, repeated measures analysis reported no significant difference in the HEI-2020 total and components between groups and across time points, a finding concurrent with results reported through the population ratio method. Future studies that use a similar macros code to calculate HEI-2020 scores should consider whether or not covariates may attenuate findings, even though no method currently exists for statistical analysis of covariates through the population ratio method.

Impact of Readiness to Change on Diet Outcomes

When participants' readiness for behavior change was considered in analyses for the effects of the intervention on diet quality, only a few significant findings were found. First, there was a marginal but statistically significant increase in participants' readiness to change from baseline to the study's endpoint across all study participants. This increase was not significantly different between groups, and given the active nature of the control group's assignment, this suggests that the very act of participation in a dietary behavior change study may have slightly elevated readiness to change. However, it is worth noting that the mean readiness to change score remained in what is considered as the "contemplation stage" of behavior change at study follow-up. Second, examination of simple unadjusted correlations revealed that a higher reported readiness to change was significantly and directly associated with sodium scores during week 4. Also, week 4 compliance with the refined grains component improved with higher baseline readiness to change scores after adjusting for covariates, regardless of group assignment, although this effect was no longer apparent by week 8. Interestingly, baseline readiness to change moderated the effect of group assignment on the HEI-2020 sugar component scores, such that the control group exhibited greater compliance with the DGAs for sugar intake with higher baseline readiness to change scores versus decreased compliance in the intervention group. One possible explanation for this is rooted in the nature of the interventions offered to students and their personal interpretation of how to improve diet. In the experimental group, students self-selected a specified, tailored dietary intervention, and among the available options, reducing added sugar intake was infrequently selected. For the control group, students received comparatively more generic advice by reading the current DGAs and considering the principles in relation to their own diet. Students in the experimental group were expected to focus on their selected specific dietary behaviors, while students in the control group were left to their own judgment for how to implement what they read in the DGAs. Since many people readily identify added sugar as a poor dietary choice, those more motivated to change in the control group could have focused on reducing added sugar intake.[33,188] Another explanation could be that the experimental group's HEI-2020 sugar component scores were higher at each time point compared to the control, though non-significantly, indicating greater compliance to the DGAs for this component. Thus, students in the experimental group may not have felt they needed to improve their sugar intake. Regardless, the HEI-2020 sugar scores for this study were unexpectedly high across all participants, as prior studies report young adults generally consume the most calories from SSBs compared to other age groups, with average daily intake sometimes exceeding 340 kcals.[37,38]

Collectively, these findings suggest student readiness to change at baseline was more important in predicting dietary outcomes than how much their readiness to change increased or decreased. The only main effect observed for change in readiness to change scores across the intervention was on sugar intake, where improvement in readiness to change over time was associated with improved compliance after adjusting for covariates, regardless of group assignment. A reduction in added sugar intake correlating with elevated readiness to change is consistent with previous literature assessing SSB intake among college students, reporting that significantly more students in the Action and Maintenance stage of change had the lowest SSB intake when compared to students in the Precontemplation and Contemplation stage.[189] Elevated fruit and vegetable intake was also reported among a predominantly female group of college students who self-reported as having a high readiness to change, compared to students with lower reported readiness to change.[190] Though added sugar and intake of fresh produce are only two components of overall diet quality, these results provide preliminary evidence that readiness to change is associated with at least a few relevant components of diet.

Feasibility and Intervention Rationale

A major rationale for this study's approach to improving diet quality was to allow participants to select what they wanted to improve in their diets, with the assumption that focusing on their own dietary interest paired with an easy change would promote a sense of perceived behavioral control and help sustain actionable change.[108,109] This was not reflected in the data, as the most commonly selected tags, fruit and vegetable promotion, did not result in any improvement between or within groups for the respective diet component scores they influence. It is possible that students chose tags to improve dietary practices that were already consistently practiced, as evidenced by the relatively high baseline scores for fruit and vegetable components in the experimental group. Indeed, the component scores that needed the most improvement had their associated tags selected the least, such as dairy promotion or processed meat reduction. Furthermore, repeated measures analysis for the most commonly selected tags did not report any significant changes for their intended components across time points. Those who selected the fruit tag did report improvement in adherence to the DGAs for sugar intake, but selection of the whole grains tag resulted in poorer compliance with the whole fruit component. These changes serve as preliminary evidence of how an intervention focusing on one aspect of the diet can effectively displace consumption of other items, either to the benefit or detriment of overall diet quality.

Despite the general ineffectiveness of this intervention for improving overall diet quality among a sample of college students, evidence suggests it was received as both feasible and had a high compliance rate. ITT analysis showed no significant changes to component scores compared to the original analysis, meaning the attrition rate was low and compliance was high.[191] Additional data from the feasibility survey suggest the high compliance rate was reflective of their interest in the actual intervention, and not merely the result of the study design which included a run-in period to assess motivation and minimal time commitments for students.[192] Interestingly, students in both the control and experimental groups reported enjoyment of the study and participation therein, prompting questions as to whether or not any changes in diet quality are driven by the intervention or elevated dietary consciousness as a result of participating in a diet-related study.[193]

Strengths and Limitations

This study contributes to existing literature on dietary interventions for college students with evidence that a simple, small behavior change intervention selected with student input and personalization does not necessarily lead to improved diet quality. The study was strengthened by several robust methodological approaches. Firstly, through repeated, interviewer-led, 24-hour recalls, we were able to reduce variance within student dietary records and increase the likelihood of a more complete record of daily intake that is reflective of students' usual dietary habits.[141] Second, we computed HEI-2020 scores using the population ratio method which reduces bias for comparisons among diet intervention groups, compared to alternative methods for calculating HEI-2020 scores.[177] Third, the participants were drawn from large and ethnically diverse universities, and despite low participation from Black and Native American students, the results are more generalizable among U.S. college students compared to previously published literature among more racial or ethnically homogenous cohorts.[126,161] The generalizability of this study was further strengthened given the range of reported college majors, providing evidence of participation from students who do not necessarily possess a general interest in health. However, the study is also subject to some limitations. The participants in the control group had an active assignment distinct from the experimental group, and outside what would qualify as everyday behavior (i.e., reading the DGAs), and this possibly reduced likelihood of finding significant differences. In spite of its racially diverse participant sample, the majority of the participants in this study were female, a feature common to many health-related studies, making it difficult to rule out the possibility of effects due to gender bias.[162] When having students in the experimental group select their tags, using a standardized order for displaying the tag options could have influenced students in selecting the first few tags most frequently (i.e., tags focused on fruit and vegetable intakes), which may explain why there was such an uneven distribution of tag selections. Furthermore, the poorest dietary component score observed in the population was for sodium, and there was no tag that directly addressed this component of the diet.

Conclusions and Future Implications

While this study's intervention was unable to significantly improve diet quality in college students, overall diet quality was poor according to the DGAs. Notably, some components of the HEI-2020 were better than others which suggests future studies should attempt to identify the diet components that actively need improvement. Future studies attempting to improve diet quality in college students should carefully consider options that are made available when tailoring the intervention. For example, given the largely null findings from this trial, a follow-up study might consider assessing participants' diet quality at baseline and calculating HEI-2020 component scores. Analysis of individual diet scores would reveal the poorest components in need of improvement, and only these components would be presented to the participant for selection as part of the intervention. Another consideration is to provide additional prompts from the research team to intervention group participants, reminding or encouraging them regarding a selected dietary behavior. Furthermore, future simple dietary behavior interventions targeting student populations should consider an appropriate activity for the control group that is not immediately related to nutrition but associated with the student experience, such as stress or time management materials. In order to effectively improve diet quality in college students, researchers may need to strike a careful balance between low-intensity interventions that promote compliance among participants and sufficiently tailored or guided interventions that have capacity to accomplish the intended aim of the study and improve dietary practices.

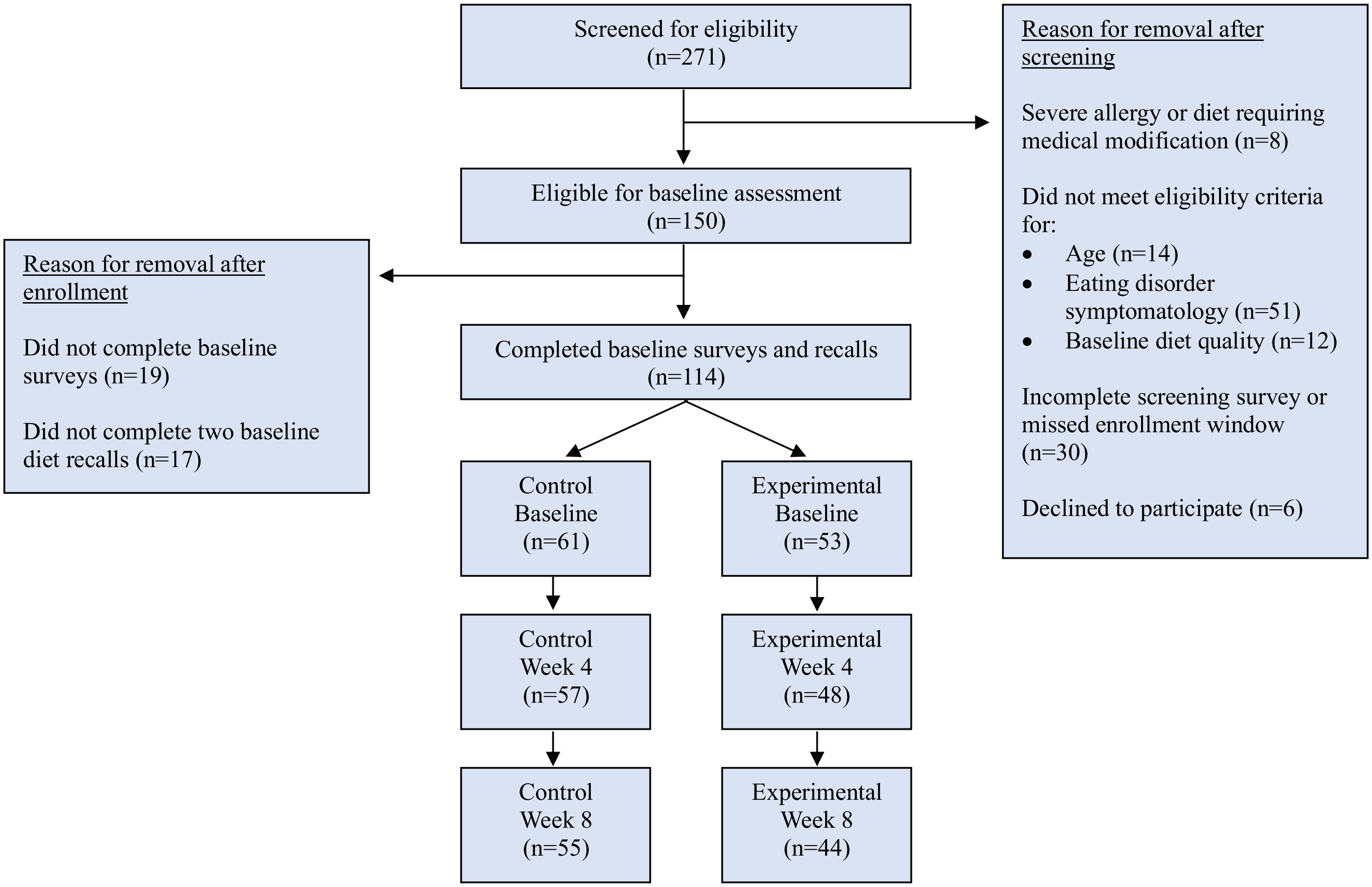

Figure 3. 1 Flowchart of participants from initial screening to final data collection.

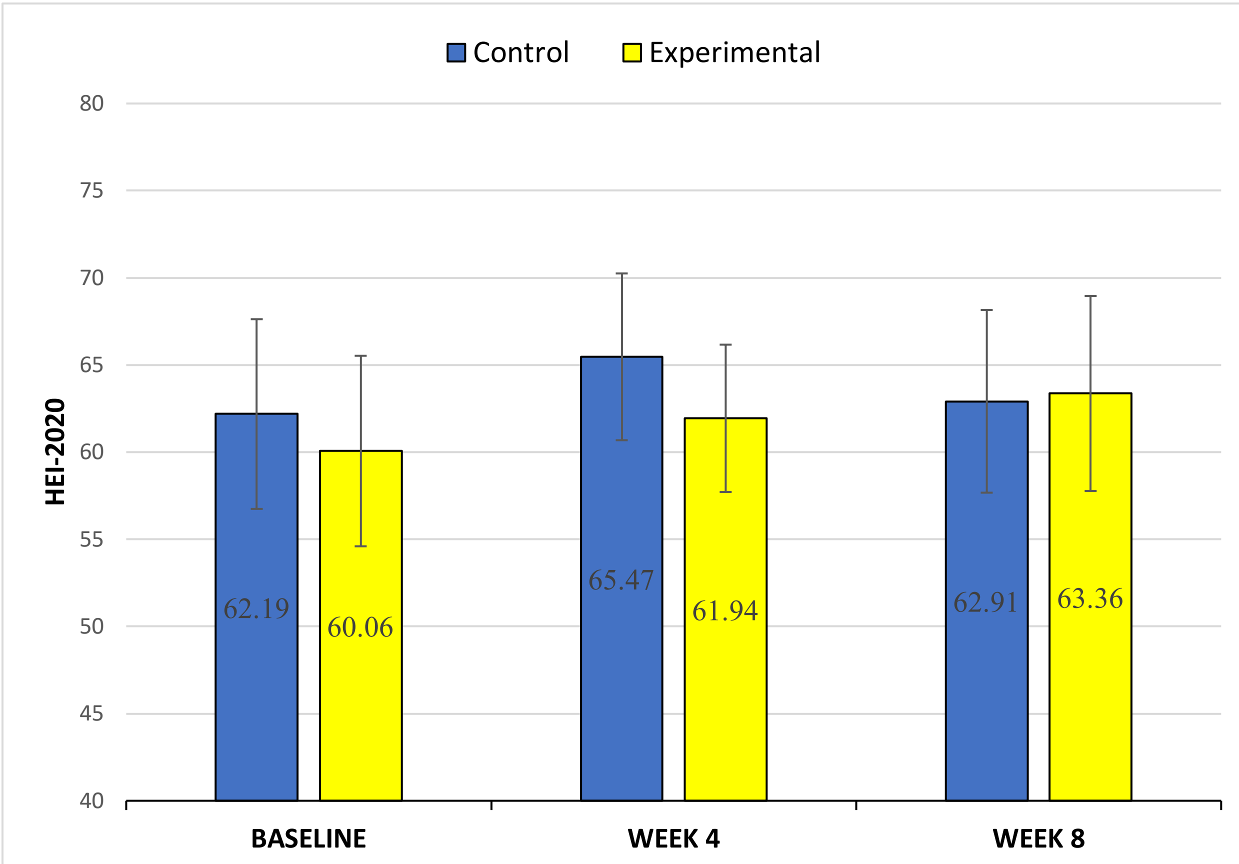

Figure 3.2 Healthy Eating Index-2020 (HEI-2020) scores and confidence intervals (CI) by assessment time point and group. Displayed scores were calculated using the population ratio method which is validated for between group comparisons in intervention trials. If CIs overlap between groups, or across timepoints, it is concluded there is no statistically significant difference. For HEI-2020, there were no significant differences between groups or across assessment time points.

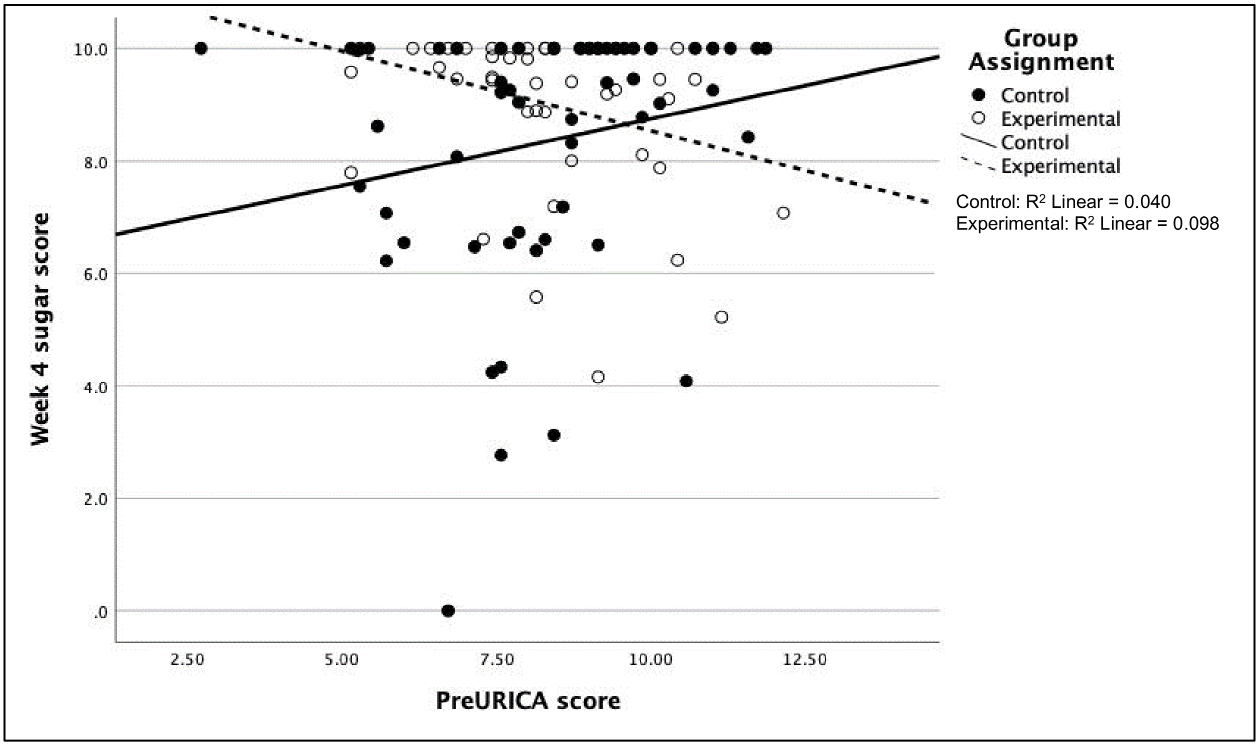

Figure 3.3 Scatterplot of the effect of group assignment on week 4 Healthy Eating Index-2020 sugar score according to baseline level of readiness to change. Abbreviations: PreURICA, Baseline University of Rhode Island Change Assessment

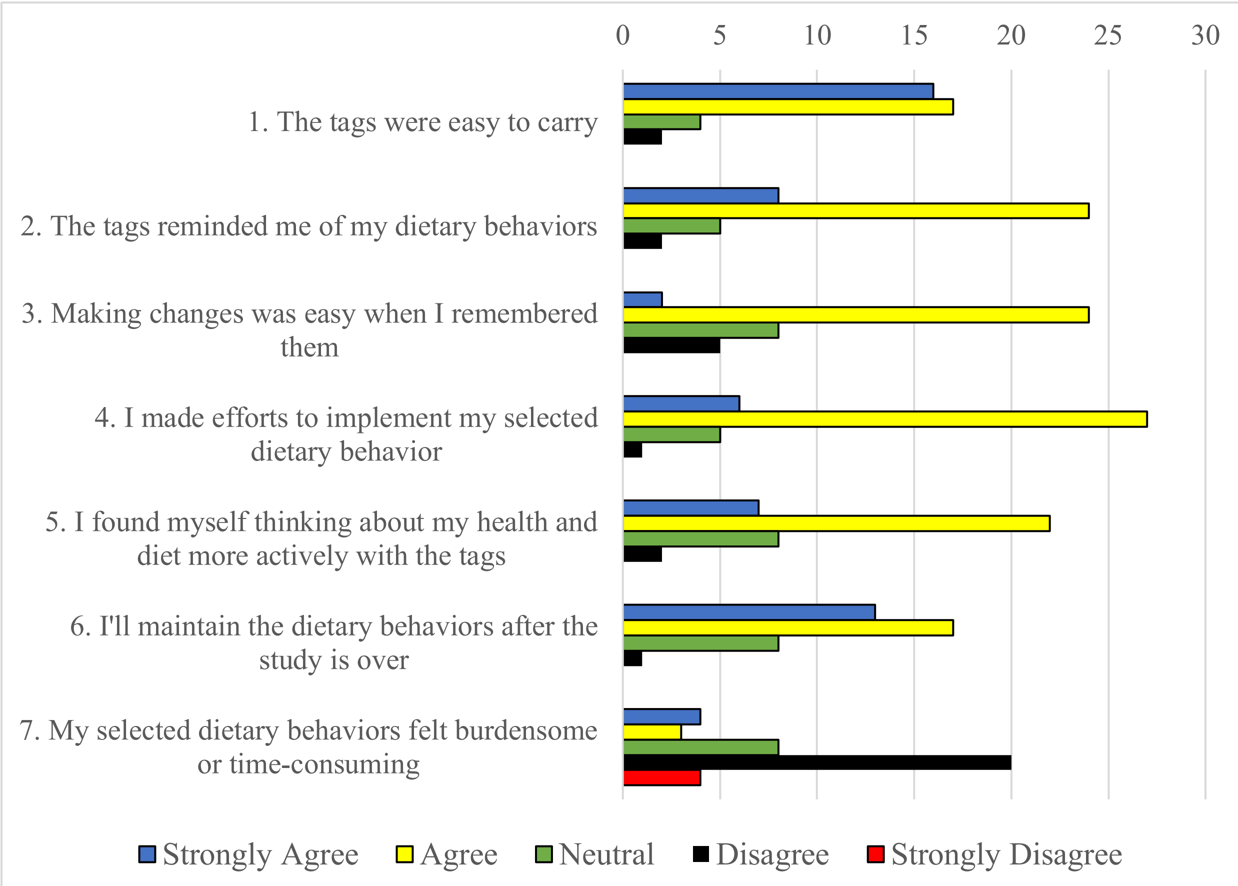

Figure 3.4 Survey Responses from participants in the experimental group (n=39) who completed the feasibility questionnaire

TABLE 3.1: Baseline characteristics and readiness to change of study participants (n=114)

Demographic Variable	Total mean (SD) or N (%)	Control (n=61)	Experimental (n=53)	p Value
Age[1] (years)	20.0 (2.0)	20.0 (2.0)	21.0 (3.0)	0.151
BMI[1] (kg/m^2)	22.6 (4.3)	21.5 (4.6)	23.0 (5.0)	0.080
Sex				0.103
Male	20 (17.5)	14	6	
Female	94 (82.5)	47	47	
Race				0.313
Asian/Asian American	39 (34.2)	20	19	
Hispanic/Latino	38 (33.3)	23	15	
White	16 (14)	6	10	
Black/African American	6 (5.3)	5	1	
Other	15 (13.2)	7	8	
Residence				0.390
Campus or university housing	35 (30.7)	18	17	
Off-campus or temporary residence with relative, friend, or acquaintance	35 (30.7)	22	13	
Parent/Guardian/Other family member's home	44 (38.6)	21	23	
Food Security Status				0.880
Food secure	91 (79.8)	49	42	
Food insecure	23 (20.2)	12	11	
PSS-10 at baseline	18.9 (5.3)	19.3 (5.8)	18.5 (4.7)	0.411
PreURICA	8.3 (1.8)	8.2 (2.0)	8.3 (1.5)	0.800
HEI-2020 total score[2]	55.3 (13.8)	55.9 (14.9)	54.8 (12.5)	0.672

SD, Standard Deviation; BMI, Body Mass Index; PSS-10, Perceived Stress Scale; URICA, University of Rhode Island Change Assessment Scale; HEI-2020, Healthy Eating Index 2020

[1]Figures are reported in medians (interquartile range)

[2]HEI-2020 scores reflect standard means not calculated using the population ratio method

TABLE 3.2: Tags Selected by Experimental Group

Dietary focus of tag	**Number of times a tag was selected**	**Text of tag**
Whole grain promotion	n=12	I will select whole-grain options (whole-wheat bread, brown rice, whole-wheat tortilla) instead of refined grains, whenever I have the choice
Vegetable promotion	n=26	Today I will consume 1 serving (1 cup) of vegetables during [*select a meal period*] and 2 servings during [*select a meal period*]
Fruit promotion	n=28	I will aim for 2 servings (2 cups) of fruit today, without any fruit juice
Dairy promotion	n=5	I will choose at least 2 servings (2 cups) of dairy products today, or, unsweetened soy milk/yogurt as a dairy alternative
Plant-based protein promotion	n=11	I will choose at least 1 plant-based protein (nuts, seeds, tofu, edamame, tempeh, beans, or lentils) option during [*select a meal period*]
Sugar sweetened beverage reduction	n=19	Whenever I feel like a soda or sugar-sweetened beverage, I will instead choose [*select water or a flavored, zero-calorie beverage*]
Fried or processed meat reduction	n=5	Instead of choosing a fried or processed meat (such as salami or bologna), I'll replace these with lean meats, poultry, or fish options

TABLE 3.3: Results of assigned intervention on HEI-2020 total and component scores

HEI-2020 & Components	BASELINE						WEEK 4						WEEK 8					
	Control			Experimental			Control			Experimental			Control			Experimental		
	Mean	Lower CI	Upper CI	Mean	Lower CI	Upper CI	Mean	Lower CI	Upper CI	Mean	Lower CI	Upper CI	Mean	Lower CI	Upper CI	Mean	Lower CI	Upper CI
Total Vegetables	3.31[1]	2.88	3.78	3.81	3.22	4.44	4.60[1]	3.83	5.00	4.14	3.55	4.77	3.52	2.98	4.07	4.52	3.80	5.00
Greens & Beans	3.46	2.23	4.73	4.69	3.34	5.00	4.66	3.34	5.00	4.94	4.22	5.00	3.98	2.00	5.00	4.96	4.34	5.00
Total Fruit	3.52	2.32	4.74	2.91	2.10	3.76	3.61	2.73	4.51	3.32	2.50	4.20	3.58	2.49	4.67	2.72	1.90	3.58
Whole Fruit	4.90	3.92	5.00	4.14	2.87	5.00	4.79	3.66	5.00	4.84	3.90	5.00	4.70	3.33	5.00	4.09	2.51	5.00
Whole Grains	3.21	2.40	4.05	2.98	2.06	3.90	3.44	2.44	4.41	2.62	1.66	3.61	2.83	1.99	3.71	3.43	2.21	4.71
Dairy	5.77	4.68	6.85	5.65	4.75	6.55	5.18	4.40	5.98	6.67	5.61	7.71	5.12	4.18	6.03	4.86	4.00	5.72
Total Protein	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00
Seafood & Plant Proteins	4.85	3.97	5.00	4.90	3.91	5.00	5.00	5.00	5.00	4.95	4.30	5.00	4.96	4.44	5.00	4.97	4.50	5.00
Fatty Acid Ratio	5.73	4.48	7.13	5.48	4.10	6.98	5.96	4.85	7.16	4.75	3.67	5.94	6.20	5.07	7.40	6.44	5.20	7.82
Sodium	2.30	1.03	3.57	0.59	0.00	1.78	2.13	0.78	3.43	1.63	0.44	2.75	2.53	1.30	3.74	1.47	0.00	2.97
Refined Grains	5.70	4.47	6.90	5.83	4.30	7.35	5.58	4.21	6.91	5.01	3.57	6.49	5.80	4.62	6.95	5.81	4.72	6.93
Saturated Fat	6.21	5.17	7.31	5.45	4.49	6.43	6.52	5.59	7.47	4.84	3.83	5.89	6.00	5.15	6.85	5.75	4.67	6.90
Added Sugar	8.22	7.46	8.96	8.63	7.82	9.42	9.01	8.26	9.73	9.23	8.61	9.90	8.69	7.88	9.48	9.34	8.51	10.00
Total HEI-2020	62.19	56.48	67.43	60.06	54.20	65.16	65.47	60.42	69.99	61.94	57.49	65.97	62.91	57.29	67.77	63.36	57.74	68.77

HEI-2020, Healthy Eating Index 2020; CI, Confidence Intervals

[1]Designates a significant difference where $p<0.05$.

TABLE 3.4: Pearson Correlation Coefficients between readiness to change scores (URICA) and HEI-2020 total and component scores

HEI Component	Pearson Correlation	Correlations with baseline diet scores		Correlations with Week 4 diet scores		Correlations with Week 8 diet scores	
		PreURICA score	Change in URICA score	PreURICA score	Change in URICA score	PreURICA score	Change in URICA score
HEI-2020 score	r	-0.008	0.029	0.140	-0.090	0.099	0.052
	p-value	0.930	0.775	0.157	0.379	0.328	0.608
Whole fruit	r	-0.070	-0.068	0.147	-0.039	0.022	0.035
	p-value	0.462	0.504	0.136	0.705	0.829	0.734
Total Vegetable	r	0.073	-0.074	0.177	-0.095	-0.100	0.119
	p-value	0.440	0.468	0.072	0.354	0.324	0.243
Greens and beans	r	-0.048	0.062	0.064	0.038	0.054	-0.109
	p-value	0.613	0.547	0.517	0.708	0.597	0.285
Total protein	r	0.070	-0.037	0.110	-0.031	0.100	-0.011
	p-value	0.458	0.718	0.264	0.765	0.325	0.911
Seafood and plant protein	r	-0.050	0.081	0.071	0.040	0.035	0.028
	p-value	0.594	0.430	0.475	0.700	0.728	0.786
Whole grains	r	0.024	0.095	-0.103	0.065	0.113	0.084
	p-value	0.796	0.350	0.297	0.525	0.265	0.408
Dairy	r	0.116	-0.032	0.034	-0.093	0.144	-0.035
	p-value	0.220	0.754	0.730	0.366	0.156	0.732
Fatty acid	r	-0.001	0.007	0.140	-0.098	0.036	0.043
	p-value	0.990	0.947	0.156	0.339	0.723	0.674
Refined grains	r	0.092	-0.089	-0.041	-0.033	0.088	0.058
	p-value	0.331	0.385	0.676	0.752	0.385	0.570
Sodium	r	0.005	-0.046	0.287	-0.162	-0.050	-0.036
	p-value	0.957	0.655	***0.003***	0.113	0.622	0.724
Sugars	r	-0.077	0.109	-0.012	0.066	0.046	0.174
	p-value	0.416	0.285	0.908	0.520	0.649	0.086
Saturated fatty acid	r	-0.099	0.101	0.042	-0.035	0.032	-0.101
	p-value	0.296	0.320	0.670	0.736	0.754	0.323
Total fruit	r	-0.109	0.018	-0.158	0.029	-0.006	0.094
	p-value	0.248	0.858	0.110	0.774	0.953	0.359

URICA, University of Rhode Island Change Assessment Scale; HEI-2020, Healthy Eating Index 2020

TABLE 3.5: Effect of group assignment and baseline readiness to change scores (PreURICA) as predictors of Healthy Eating Index-2020 scores at week 4

	Variables	Model 1					Model 2					Model 3				
		β	SE	95% CI (Lower/Upper)		P	β	SE	95% CI (Lower/Upper)		P	β	SE	95% CI (Lower/Upper)		P
Total Fruit Score	Age (years)	-0.126	0.108	-0.341	0.089	0.248	0.114	-0.157	-0.395	0.057	0.141	0.115	-0.164	-0.404	0.052	0.129
	Race	0.099	0.143	-0.184	0.382	0.490	0.143	0.067	-0.189	0.379	0.508	0.144	0.064	-0.195	0.376	0.530
	BMI (kg/m²)	0.099	0.045	0.009	0.188	***0.032***	0.048	0.169	-0.017	0.174	0.107	0.049	0.161	-0.022	0.171	0.129
	PreURICA						0.121	0.134	-0.091	0.390	0.220	0.143	0.092	-0.182	0.387	0.476
	Group						0.387	0.026	-0.668	0.869	0.796	1.934	-0.275	-4.918	2.759	0.578
	PreURICA x Group											0.229	0.313	-0.312	0.597	0.535
	R^2		0.056			0.120		0.071			0.196		0.075			0.261
Whole Fruit Score	Age (years)	-0.023	0.122	-0.266	0.220	0.849	-0.094	0.127	-0.345	0.157	0.460	-0.106	0.127	-0.359	0.146	0.405
	Race	0.151	0.161	-0.168	0.471	0.350	0.134	0.159	-0.182	0.450	0.401	0.126	0.159	-0.191	0.442	0.432
	BMI (kg/m²)	0.062	0.051	-0.039	0.164	0.227	0.026	0.054	-0.080	0.132	0.629	0.019	0.054	-0.088	0.126	0.727
	PreURICA						0.217	0.135	-0.050	0.484	0.111	0.130	0.159	-0.185	0.445	0.414
	Group						0.693	0.431	-0.161	1.547	0.111	-1.484	2.142	-5.736	2.768	0.490
	PreURICA x Group											0.263	0.253	-0.240	0.766	0.302
	R^2		0.024			0.480		0.071			0.198		0.081			0.212
Total Vegetable Score	Age (years)	-0.017	0.079	-0.172	0.139	0.833	-0.042	0.083	-0.206	0.122	0.613	-0.049	0.083	-0.214	0.117	0.560
	Race	-0.024	0.103	-0.229	0.181	0.819	-0.026	0.104	-0.232	0.181	0.805	-0.030	0.104	-0.238	0.177	0.771
	BMI (kg/m²)	-0.015	0.033	-0.080	0.050	0.646	-0.027	0.035	-0.097	0.043	0.444	-0.031	0.035	-0.101	0.039	0.386
	PreURICA						0.088	0.088	-0.087	0.263	0.318	0.041	0.104	-0.165	0.247	0.694
	Group						0.054	0.282	-0.505	0.613	0.848	-1.135	1.404	-3.921	1.651	0.421
	PreURICA x Group											0.144	0.166	-0.186	0.473	0.389
	R^2		0.004			0.943		0.014			0.923		0.022			0.904

	Variables	Model 1					Model 2					Model 3				
		β	SE	95% CI (Lower/Upper)		P	β	SE	95% CI (Lower/Upper)		P	β	SE	95% CI (Lower/Upper)		P
Green Beans Score	Age (years)	0.156	0.122	-0.086	0.397	0.203	0.114	0.128	-0.140	0.368	0.376	0.104	0.129	-0.151	0.360	0.420
	Race	0.159	0.160	-0.158	0.477	0.322	0.153	0.161	-0.167	0.472	0.345	0.146	0.162	-0.175	0.467	0.368
	BMI (kg/m²)	-0.044	0.051	-0.145	0.057	0.388	-0.065	0.054	-0.172	0.043	0.237	-0.070	0.055	-0.179	0.039	0.204
	PreURICA						0.138	0.136	-0.133	0.408	0.315	0.071	0.161	-0.248	0.390	0.660
	Group						0.245	0.436	-0.620	1.109	0.576	-1.426	2.173	-5.738	2.886	0.513
	PreURICA x Group											0.202	0.257	-0.308	0.712	0.435
	R^2		0.038			0.278		0.050			0.403		0.056			0.457
Total Protein Score	Age (years)	-0.038	0.055	-0.146	0.071	0.491	-0.056	0.057	-0.170	0.058	0.332	-0.050	0.058	-0.164	0.064	0.388
	Race	0.032	0.072	-0.110	0.174	0.657	0.030	0.072	-0.113	0.173	0.677	0.034	0.072	-0.109	0.178	0.635
	BMI (kg/m²)	-0.001	0.023	-0.047	0.044	0.951	-0.010	0.024	-0.058	0.038	0.679	-0.007	0.024	-0.055	0.042	0.788
	PreURICA						0.063	0.061	-0.058	0.184	0.304	0.106	0.072	-0.037	0.249	0.144
	Group						0.056	0.195	-0.332	0.444	0.775	1.126	0.971	-0.801	3.054	0.249
	PreURICA x Group											-0.129	0.115	-0.357	0.099	0.263
	R^2		0.006			0.903		0.017			0.889		0.030			0.813
Seafood and Protein Score	Age (years)	-0.210	0.115	-0.437	0.018	0.070	-0.208	0.121	-0.449	0.033	0.090	-0.218	0.122	-0.461	0.024	0.076
	Race	0.261	0.151	-0.039	0.560	0.087	0.265	0.153	-0.037	0.568	0.085	0.258	0.153	-0.046	0.561	0.095
	BMI (kg/m²)	-0.098	0.048	-0.193	-0.003	***0.043***	-0.096	0.051	-0.198	0.006	0.065	-0.102	0.052	-0.205	0.001	0.051
	PreURICA						0.003	0.129	-0.253	0.260	0.979	-0.072	0.152	-0.374	0.230	0.635
	Group						-0.220	0.413	-1.039	0.599	0.595	-2.121	2.056	-6.201	1.959	0.305
	PreURICA x Group											0.230	0.243	-0.253	0.712	0.348
	R^2		0.089			0.025		0.091			0.090		0.099			0.110

		Model 1					Model 2					Model 3				
	Variables	β	SE	95% CI (Lower/Upper)		P	β	SE	95% CI (Lower/Upper)		P	β	SE	95% CI (Lower/Upper)		P
Whole Grains Score	Age (years)	0.132	0.177	-0.219	0.483	0.458	0.163	0.186	-0.206	0.532	0.382	0.168	0.187	-0.204	0.540	0.372
	Race	0.602	0.233	0.140	1.064	***0.011***	0.620	0.233	0.157	1.084	0.009	0.624	0.235	0.158	1.090	0.009
	BMI (kg/m²)	0.020	0.074	-0.126	0.167	0.784	0.039	0.079	-0.117	0.196	0.617	0.042	0.080	-0.116	0.200	0.595
	PreURICA						-0.070	0.198	-0.463	0.322	0.723	-0.034	0.234	-0.498	0.430	0.883
	Group						-0.810	0.632	-2.064	0.443	0.203	0.090	3.159	-6.180	6.359	0.977
	PreURICA x Group											-0.109	0.374	-0.850	0.633	0.772
	R^2		0.083			***0.034***		0.099			0.066		0.100			0.110
Dairy Score	Age (years)	0.136	0.150	-0.163	0.434	0.369	0.086	0.157	-0.226	0.398	0.585	0.085	0.159	-0.229	0.400	0.592
	Race	0.380	0.198	-0.013	0.772	0.058	0.361	0.197	-0.031	0.752	0.071	0.360	0.199	-0.034	0.754	0.073
	BMI (kg/m²)	0.055	0.063	-0.070	0.179	0.386	0.027	0.066	-0.105	0.159	0.684	0.027	0.067	-0.107	0.160	0.692
	PreURICA						0.135	0.167	-0.196	0.467	0.420	0.131	0.198	-0.262	0.523	0.511
	Group						0.822	0.534	-0.237	1.882	0.127	0.704	2.671	-4.597	6.005	0.793
	PreURICA x Group											0.014	0.316	-0.613	0.641	0.964
	R^2		0.065			0.080		0.092			0.088		0.092			0.146
Fatty Acid Score	Age (years)	-0.419	0.171	-0.758	-0.080	***0.016***	-0.456	0.179	-0.811	-0.101	0.012	-0.442	0.180	-0.799	-0.084	0.016
	Race	-0.045	0.225	-0.491	0.401	0.841	-0.032	0.225	-0.478	0.415	0.889	-0.022	0.226	-0.469	0.426	0.924
	BMI (kg/m²)	-0.093	0.071	-0.234	0.049	0.198	-0.105	0.076	-0.255	0.045	0.169	-0.097	0.076	-0.249	0.055	0.209
	PreURICA						0.170	0.190	-0.208	0.548	0.375	0.271	0.225	-0.174	0.717	0.230
	Group						-0.700	0.608	-1.908	0.507	0.253	1.848	3.033	-4.172	7.868	0.544
	PreURICA x Group											-0.308	0.359	-1.020	0.404	0.393
	R^2		0.085			***0.031***		0.105			0.050		0.112			0.068

	Variables	Model 1					Model 2					Model 3				
		β	SE	95% CI (Lower/Upper)		P	β	SE	95% CI (Lower/Upper)		P	β	SE	95% CI (Lower/Upper)		P
Refined Grains Score	Age (years)	0.255	0.209	-0.160	0.670	0.226	0.098	0.215	-0.328	0.524	0.649	0.087	0.216	-0.342	0.516	0.688
	Race	0.471	0.275	-0.075	1.017	0.090	0.470	0.270	-0.065	1.006	0.084	0.463	0.271	-0.075	1.001	0.091
	BMI (kg/m^2)	0.036	0.087	-0.137	0.209	0.681	-0.033	0.091	-0.214	0.147	0.713	-0.040	0.092	-0.222	0.143	0.667
	PreURICA						0.575	0.228	0.122	1.028	***0.013***	0.498	0.270	-0.037	1.034	0.068
	Group						-0.242	0.729	-1.690	1.205	0.740	-2.158	3.644	-9.391	5.075	0.555
	PreURICA x Group											0.231	0.431	-0.624	1.087	0.593
	R^2	0.059				0.107	0.118				***0.029***	0.120				***0.048***
Sodium Score	Age (years)	-0.332	0.155	-0.640	-0.024	***0.035***	-0.338	0.163	-0.662	-0.014	0.041	-0.345	0.165	-0.672	-0.018	0.039
	Race	0.730	0.204	0.324	1.135	***0.001***	0.742	0.205	0.335	1.150	0.000	0.738	0.206	0.328	1.147	0.001
	BMI (kg/m^2)	-0.022	0.065	-0.150	0.107	0.738	-0.021	0.069	-0.158	0.116	0.765	-0.024	0.070	-0.163	0.114	0.727
	PreURICA						0.055	0.174	-0.290	0.399	0.754	0.008	0.205	-0.400	0.415	0.970
	Group						-0.621	0.555	-1.722	0.481	0.266	-1.793	2.774	-7.299	3.712	0.519
	PreURICA x Group											0.142	0.328	-0.510	0.793	0.667
	R^2	0.127				***0.003***	0.139				***0.011***	0.141				***0.020***
Sugar Score	Age (years)	0.055	0.110	-0.164	0.274	0.622	0.025	0.115	-0.204	0.253	0.832	0.049	0.113	-0.176	0.273	0.668
	Race	0.035	0.145	-0.254	0.323	0.812	0.019	0.145	-0.268	0.306	0.896	0.036	0.142	-0.246	0.317	0.801
	BMI (kg/m^2)	-0.029	0.046	-0.120	0.063	0.536	-0.047	0.049	-0.143	0.050	0.341	-0.033	0.048	-0.128	0.063	0.498
	PreURICA						0.072	0.122	-0.171	0.315	0.556	0.243	0.141	-0.037	0.523	0.089
	Group						0.691	0.391	-0.085	1.467	0.080	4.962	1.906	1.178	8.746	0.011
	PreURICA x Group											-0.516	0.226	-0.963	-0.068	***0.024***
	R^2	0.007				0.876	0.040				0.543	0.089				0.161

	Variables	Model 1					Model 2					Model 3				
		β	SE	95% CI (Lower/Upper)		P	β	SE	95% CI (Lower/Upper)		P	β	SE	95% CI (Lower/Upper)		P
Saturated Fatty Acid Score	Age (years)	-0.433	0.165	-0.760	-0.106	***0.010***	-0.407	0.173	-0.751	-0.064	0.021	-0.404	0.175	-0.751	-0.058	0.023
	Race	-0.398	0.217	-0.828	0.033	***0.070***	-0.379	0.217	-0.810	0.052	0.084	-0.377	0.219	-0.811	0.057	0.088
	BMI (kg/m^2)	-0.093	0.069	-0.230	0.043	0.178	-0.077	0.073	-0.222	0.069	0.298	-0.075	0.074	-0.222	0.072	0.316
	PreURICA						-0.048	0.184	-0.413	0.317	0.795	-0.025	0.218	-0.457	0.407	0.908
	Group						-0.847	0.588	-2.014	0.320	0.153	-0.273	2.941	-6.110	5.564	0.926
	PreURICA x Group											-0.069	0.348	-0.760	0.621	0.842
	R^2	0.143				***0.001***	0.161				***0.004***	0.161				***0.008***
HEI-2020 Total Score	Age (years)	-0.865	0.733	-2.319	0.590	0.241	-1.285	0.762	-2.798	0.228	0.095	-1.296	0.770	-2.824	0.231	0.095
	Race	2.452	0.965	0.538	4.367	***0.013***	2.454	0.958	0.552	4.355	0.012	2.446	0.964	0.532	4.360	0.013
	BMI (kg/m^2)	-0.124	0.306	-0.731	0.484	0.687	-0.309	0.323	-0.949	0.331	0.341	-0.315	0.327	-0.964	0.333	0.337
	PreURICA						1.548	0.811	-0.062	3.157	0.059	1.469	0.960	-0.436	3.374	0.129
	Group						-0.779	2.592	-5.922	4.364	0.764	-2.739	12.967	-28.474	22.997	0.833
	PreURICA x Group											0.237	1.534	-2.808	3.282	0.878
	R^2	0.065				0.082	0.100				0.064	0.100				0.109

BMI, Body Mass Index; CI, Confidence Interval; HEI-2020, Healthy Eating Index 2020; PreURICA, Baseline University of Rhode Island Change Assessment Scale; SE, Standard Error

Table 3.6: Effect of group assignment and changes in readiness to change scores across the study on Healthy Eating Index-2020 scores at week 8

	Variables	Model 1 β	Model 1 SE	Model 1 95% CI (Lower/Upper)		Model 1 P	Model 2 β	Model 2 SE	Model 2 95% CI (Lower/Upper)		Model 2 P	Model 3 β	Model 3 SE	Model 3 95% CI (Lower/Upper)		Model 3 P
Total Fruit Score	Age (years)	-0.173	0.113	-0.399	0.052	0.130	-0.204	0.122	-0.446	0.038	0.098	-0.205	0.123	-0.450	0.040	0.099
	Race	0.009	0.150	-0.289	0.306	0.953	0.016	0.150	-0.283	0.314	0.918	0.013	0.154	-0.292	0.318	0.933
	BMI (kg/m^2)	0.025	0.048	-0.070	0.119	0.606	0.026	0.050	-0.074	0.126	0.612	0.025	0.051	-0.075	0.126	0.617
	PreURICA						0.121	0.142	-0.162	0.403	0.398	0.122	0.144	-0.163	0.408	0.397
	ΔURICA						0.226	0.176	-0.124	0.576	0.203	0.244	0.251	-0.254	0.742	0.333
	Group						-0.321	0.404	-1.124	0.481	0.428	-0.312	0.418	-1.142	0.518	0.457
	ΔURICA x Group											-0.031	0.315	-0.657	0.595	0.921
	R^2		0.026			0.469		0.051			0.558		0.051			0.676
Whole Fruit Score	Age (years)	-0.143	0.126	-0.393	0.106	0.256	-0.188	0.135	-0.457	0.081	0.168	-0.194	0.137	-0.466	0.078	0.160
	Race	0.036	0.166	-0.293	0.365	0.829	0.038	0.167	-0.294	0.371	0.820	0.027	0.171	-0.312	0.366	0.876
	BMI (kg/m^2)	-0.027	0.053	-0.132	0.077	0.603	-0.037	0.056	-0.148	0.074	0.510	-0.038	0.056	-0.150	0.074	0.503
	PreURICA						0.162	0.158	-0.152	0.476	0.309	0.169	0.160	-0.149	0.486	0.294
	ΔURICA						0.137	0.196	-0.252	0.527	0.485	0.215	0.279	-0.339	0.768	0.443
	Group						-0.256	0.450	-1.149	0.637	0.571	-0.214	0.464	-1.136	0.709	0.647
	ΔURICA x Group											-0.137	0.350	-0.833	0.559	0.696
	R^2		0.018			0.640		0.033			0.788		0.035			0.856
Total Vegetable Score	Age (years)	0.024	0.086	-0.147	0.195	0.780	0.041	0.091	-0.140	0.221	0.656	0.043	0.092	-0.139	0.226	0.639
	Race	0.055	0.114	-0.171	0.281	0.630	0.052	0.112	-0.171	0.275	0.646	0.057	0.115	-0.171	0.285	0.621
	BMI (kg/m^2)	0.008	0.036	-0.064	0.080	0.828	0.016	0.038	-0.058	0.091	0.667	0.017	0.038	-0.059	0.092	0.662
	PreURICA						-0.076	0.106	-0.287	0.135	0.475	-0.079	0.107	-0.293	0.134	0.462
	ΔURICA						0.094	0.132	-0.168	0.356	0.477	0.060	0.187	-0.312	0.432	0.750
	Group						0.569	0.302	-0.030	1.169	0.062	0.551	0.312	-0.069	1.170	0.081
	ΔURICA x Group											0.061	0.235	-0.407	0.528	0.797
	R^2		0.005			0.927		0.065			0.399		0.065			0.510

	Variables	Model 1 β	SE	95% CI (Lower/Upper)		P	Model 2 β	SE	95% CI (Lower/Upper)		P	Model 3 β	SE	95% CI (Lower/Upper)		P
Green Beans Score	Age (years)	0.097	0.126	-0.153	0.348	0.443	0.093	0.133	-0.172	0.358	0.489	0.100	0.135	-0.168	0.368	0.460
	Race	0.171	0.167	-0.160	0.502	0.308	0.154	0.165	-0.173	0.481	0.352	0.168	0.168	-0.166	0.502	0.321
	BMI (kg/m²)	-0.007	0.053	-0.112	0.098	0.894	-0.024	0.055	-0.133	0.085	0.664	-0.023	0.055	-0.133	0.087	0.678
	PreURICA						-0.030	0.156	-0.339	0.280	0.850	-0.038	0.157	-0.350	0.275	0.810
	ΔURICA						-0.206	0.193	-0.589	0.178	0.290	-0.297	0.274	-0.842	0.247	0.281
	Group						0.897	0.443	0.018	1.777	***0.046***	0.847	0.457	-0.061	1.755	0.067
	ΔURICA x Group											0.164	0.345	-0.521	0.849	0.636
	R^2		0.022			0.557		0.076			0.293		0.078			0.378
Total Protein Score	Age (years)	0.043	0.041	-0.038	0.124	0.297	0.030	0.044	-0.057	0.116	0.501	0.034	0.044	-0.054	0.122	0.442
	Race	-0.044	0.054	-0.151	0.063	0.418	-0.048	0.054	-0.155	0.059	0.378	-0.040	0.055	-0.149	0.070	0.473
	BMI (kg/m²)	0.016	0.017	-0.018	0.050	0.352	0.010	0.018	-0.025	0.046	0.565	0.011	0.018	-0.025	0.047	0.543
	PreURICA						0.033	0.051	-0.068	0.135	0.514	0.028	0.051	-0.074	0.131	0.583
	ΔURICA						0.021	0.063	-0.105	0.147	0.745	-0.035	0.090	-0.213	0.143	0.695
	Group						0.253	0.145	-0.035	0.542	0.084	0.223	0.149	-0.074	0.520	0.139
	ΔURICA x Group											0.099	0.113	-0.125	0.324	0.380
	R^2		0.025			0.488		0.060			0.449		0.068			0.479
Seafood and Protein Score	Age (years)	0.223	0.117	-0.009	0.454	0.059	0.203	0.126	-0.048	0.453	0.112	0.217	0.127	-0.036	0.469	0.092
	Race	-0.188	0.154	-0.494	0.118	0.225	-0.185	0.156	-0.495	0.125	0.238	-0.159	0.158	-0.473	0.156	0.319
	BMI (kg/m²)	-0.099	0.049	-0.196	-0.002	***0.046***	-0.104	0.052	-0.207	0.000	0.050	-0.102	0.052	-0.205	0.002	0.055
	PreURICA						0.081	0.147	-0.212	0.373	0.585	0.065	0.148	-0.230	0.359	0.664
	ΔURICA						0.042	0.183	-0.321	0.405	0.818	-0.135	0.258	-0.649	0.378	0.602
	Group						-0.292	0.419	-1.125	0.540	0.487	-0.389	0.431	-1.245	0.467	0.369
	ΔURICA x Group											0.316	0.325	-0.330	0.962	0.334
	R^2		0.079			0.052		0.087			0.207		0.096			0.227

	Variables	Model 1					Model 2					Model 3				
		β	SE	95% CI (Lower/Upper)		P	β	SE	95% CI (Lower/Upper)		P	β	SE	95% CI (Lower/Upper)		P
Whole Grains Score	Age (years)	-0.048	0.195	-0.435	0.338	0.804	-0.179	0.207	-0.590	0.231	0.388	-0.165	0.209	-0.580	0.249	0.430
	Race	0.137	0.257	-0.373	0.646	0.596	0.131	0.255	-0.376	0.639	0.608	0.157	0.260	-0.360	0.674	0.548
	BMI (kg/m^2)	0.041	0.082	-0.121	0.203	0.614	0.012	0.085	-0.157	0.182	0.886	0.014	0.086	-0.156	0.185	0.870
	PreURICA						0.426	0.241	-0.053	0.905	0.081	0.411	0.244	-0.073	0.895	0.095
	ΔURICA						0.499	0.299	-0.095	1.094	0.099	0.328	0.425	-0.516	1.172	0.442
	Group						0.407	0.686	-0.956	1.770	0.555	0.313	0.708	-1.093	1.719	0.659
	ΔURICA x Group											0.305	0.534	-0.756	1.366	0.569
	R^2		0.006			0.904		0.051			0.567		0.054			0.644
Dairy Score	Age (years)	0.021	0.164	-0.304	0.346	0.899	-0.066	0.176	-0.415	0.284	0.710	-0.032	0.175	-0.380	0.317	0.857
	Race	0.414	0.216	-0.015	0.843	0.058	0.409	0.217	-0.023	0.840	0.063	0.472	0.218	0.038	0.906	0.033
	BMI (kg/m^2)	0.006	0.069	-0.130	0.142	0.930	-0.022	0.073	-0.167	0.122	0.758	-0.018	0.072	-0.161	0.125	0.804
	PreURICA						0.288	0.205	-0.120	0.695	0.164	0.249	0.205	-0.157	0.656	0.226
	ΔURICA						0.116	0.255	-0.390	0.622	0.649	-0.305	0.357	-1.014	0.403	0.394
	Group						-0.015	0.584	-1.175	1.145	0.979	-0.245	0.594	-1.426	0.935	0.681
	ΔURICA x Group											0.750	0.448	-0.140	1.641	0.098
	R^2		0.041			0.266		0.062			0.428		0.090			0.270
Fatty Acid Score	Age (years)	0.346	0.188	-0.027	0.718	0.069	0.372	0.203	-0.031	0.776	0.070	0.329	0.202	-0.072	0.730	0.107
	Race	-0.043	0.248	-0.535	0.449	0.863	-0.034	0.251	-0.533	0.465	0.893	-0.114	0.252	-0.614	0.386	0.651
	BMI (kg/m^2)	0.061	0.079	-0.095	0.217	0.442	0.079	0.084	-0.088	0.246	0.351	0.073	0.083	-0.092	0.238	0.381
	PreURICA						-0.072	0.237	-0.543	0.399	0.763	-0.023	0.236	-0.491	0.445	0.923
	ΔURICA						0.120	0.294	-0.465	0.705	0.684	0.659	0.411	-0.157	1.475	0.112
	Group						-0.277	0.675	-1.617	1.063	0.682	0.017	0.684	-1.343	1.377	0.980
	ΔURICA x Group											-0.959	0.516	-1.985	0.067	0.067
	R^2		0.044			0.234		0.051			0.564		0.086			0.308

	Variables	Model 1					Model 2					Model 3				
		β	SE	95% CI (Lower/Upper)		P	β	SE	95% CI (Lower/Upper)		P	β	SE	95% CI (Lower/Upper)		P
Refined Grains Score	Age (years)	0.027	0.185	-0.341	0.394	0.886	-0.087	0.198	-0.480	0.306	0.662	-0.071	0.200	-0.468	0.326	0.723
	Race	0.160	0.244	-0.325	0.646	0.513	0.151	0.244	-0.334	0.637	0.538	0.181	0.249	-0.314	0.675	0.469
	BMI (kg/m^2)	-0.050	0.078	-0.204	0.104	0.519	-0.082	0.082	-0.244	0.081	0.321	-0.079	0.082	-0.242	0.084	0.336
	PreURICA						0.359	0.231	-0.100	0.818	0.123	0.341	0.233	-0.122	0.804	0.147
	ΔURICA						0.333	0.287	-0.236	0.903	0.248	0.135	0.406	-0.672	0.942	0.741
	Group						0.536	0.657	-0.769	1.840	0.417	0.428	0.677	-0.917	1.773	0.529
	ΔURICA x Group											0.353	0.511	-0.662	1.368	0.491
	R^2	0.009				0.830	0.043				0.666	0.048				0.715
Sodium Score	Age (years)	0.025	0.172	-0.317	0.367	0.883	0.086	0.185	-0.282	0.454	0.643	0.084	0.188	-0.289	0.457	0.657
	Race	0.101	0.227	-0.351	0.553	0.658	0.109	0.229	-0.346	0.565	0.634	0.105	0.234	-0.360	0.570	0.655
	BMI (kg/m^2)	-0.046	0.072	-0.189	0.097	0.527	-0.029	0.077	-0.181	0.123	0.709	-0.029	0.077	-0.182	0.124	0.708
	PreURICA						-0.178	0.216	-0.608	0.252	0.413	-0.175	0.219	-0.610	0.260	0.425
	ΔURICA						-0.205	0.269	-0.739	0.328	0.447	-0.175	0.382	-0.933	0.584	0.648
	Group						-0.633	0.616	-1.856	0.590	0.307	-0.616	0.636	-1.880	0.647	0.335
	ΔURICA x Group											-0.054	0.480	-1.008	0.899	0.910
	R^2	0.007				0.892	0.026				0.870	0.026				0.928
Sugar Score	Age (years)	0.052	0.137	-0.220	0.323	0.706	-0.027	0.142	-0.310	0.256	0.848	-0.018	0.144	-0.304	0.268	0.900
	Race	-0.189	0.180	-0.547	0.169	0.297	-0.194	0.176	-0.544	0.155	0.273	-0.177	0.179	-0.534	0.179	0.326
	BMI (kg/m^2)	0.030	0.057	-0.084	0.143	0.604	0.018	0.059	-0.099	0.135	0.760	0.019	0.059	-0.098	0.137	0.745
	PreURICA						0.240	0.166	-0.090	0.570	0.152	0.230	0.168	-0.104	0.563	0.175
	ΔURICA						0.469	0.206	0.059	0.879	***0.025***	0.355	0.293	-0.227	0.936	0.229
	Group						0.749	0.473	-0.191	1.688	0.117	0.686	0.488	-0.284	1.656	0.163
	ΔURICA x Group											0.204	0.368	-0.528	0.935	0.582
	R^2	0.014				0.711	0.092				0.176	0.095				0.238

	Variables	Model 1					Model 2					Model 3				
		β	SE	95% CI (Lower/Upper)		P	β	SE	95% CI (Lower/Upper)		P	β	SE	95% CI (Lower/Upper)		P
Saturated Fatty Acid Score	Age (years)	0.181	0.181	-0.178	0.540	0.320	0.216	0.195	-0.172	0.603	0.271	0.212	0.197	-0.180	0.604	0.286
	Race	-0.172	0.239	-0.647	0.302	0.473	-0.172	0.241	-0.651	0.307	0.477	-0.179	0.246	-0.668	0.309	0.468
	BMI (kg/m^2)	-0.022	0.076	-0.173	0.129	0.773	-0.022	0.081	-0.182	0.138	0.784	-0.023	0.081	-0.184	0.138	0.780
	PreURICA						-0.107	0.228	-0.559	0.346	0.641	-0.102	0.230	-0.560	0.355	0.659
	ΔURICA						-0.317	0.283	-0.878	0.244	0.265	-0.268	0.401	-1.065	0.530	0.506
	Group						-0.375	0.647	-1.662	0.911	0.563	-0.349	0.669	-1.678	0.981	0.604
	ΔURICA x Group											-0.088	0.505	-1.091	0.915	0.863
	R^2	0.014				0.725	0.031				0.818	0.031				0.890
HEI-2020 Total Score	Age (years)	0.674	0.824	-0.963	2.310	0.416	0.289	0.887	-1.473	2.051	0.746	0.333	0.897	-1.449	2.115	0.711
	Race	0.446	1.088	-1.715	2.607	0.683	0.427	1.096	-1.750	2.605	0.698	0.510	1.118	-1.711	2.731	0.649
	BMI (kg/m^2)	-0.065	0.345	-0.751	0.621	0.850	-0.158	0.367	-0.886	0.570	0.668	-0.152	0.368	-0.884	0.580	0.681
	PreURICA						1.248	1.035	-0.809	3.304	0.231	1.197	1.047	-0.882	3.276	0.256
	ΔURICA						1.331	1.285	-1.222	3.884	0.303	0.779	1.825	-2.846	4.404	0.671
	Group						1.241	2.945	-4.609	7.091	0.674	0.940	3.041	-5.101	6.981	0.758
	ΔURICA x Group											0.983	2.294	-3.576	5.541	0.669
	R^2	0.011				0.792	0.031				0.821	0.033				0.878

BMI, Body Mass Index; CI, Confidence Interval; HEI-2020, Healthy Eating Index 2020; PreURICA, Baseline University of Rhode Island Change Assessment Scale; SE, Standard Error; ΔURICA, Change in University of Rhode Island Change Assessment Scale

DISCUSSION, CONCLUSION, AND FUTURE DIRECTIONS FOR RESEARCH

Summary of Research Chapters

The aim of chapter 1 in this dissertation was to identify and synthesize the findings of previously published studies among young adults, aged 18-35 years, which tested the effects of easy-to-learn (ETL) interventions compared to passive or alternative treatments on overall diet quality or constituents of diet quality. ETL interventions were defined as any reportable behavior change from participants that required no more than 1 hour of engagement time to learn, not including initial survey or data collection procedures. Following independent electronic searches, studies which were eligible for review had relevant data extracted and organized within summary tables. Wherein possible, Cohen's d effect sizes were calculated for each diet-related outcome. Finally, study quality was assessed using the Quality Criteria Checklist for Primary Research, provided by the Academy of Nutrition and Dietetics.[92] Summaries of these findings were compared and reported regarding relevant conclusions and study limitations. Of all identified articles, nine met the criteria, five reported significant improvement to the selected dietary outcome between groups, and one reported improvement within the treatment group. Four studies used an implementation intentions approach that had participants write out a simple dietary behavior directive and carry it with them for the study duration, and among these, three reported significant differences between groups. The average Cohen's d for all included studies was 0.26.

These findings offer evidence that ETL interventions which target the dietary behaviors of young adults are effective for improving dietary intake. Though the calculated effect sizes were not large, this was anticipated given the simplistic and small-change nature of the interventions. Dietary interventions that target young adults do not require complex, costly, or lengthy periods of assessment to successfully modify dietary behaviors.

The aim of chapter 2 was to examine the association between perceived stress and diet quality in a diverse population of college students from two major universities in southern California, as well as assess whether food security moderates the association between diet quality and perceived stress. Existing studies typically report that high psychological stress negatively affects diet quality, but the association is not clear among college students. Data for this cross-sectional analysis was generated from baseline measures in a behavioral intervention trial that aimed to improve the diet quality of full-time enrolled college adults. Results from Pearson's and Spearman's rho correlations showed no significant associations between Healthy Eating Index-2020 (HEI-2020) scores and perceived stress or food security. Linear regression analysis reported no significant associations between perceived stress and HEI-2020 or any component of diet quality, though the associations of perceived stress with total protein and sugar component scores trended towards significance. Hierarchical regression observed no significant main effects of food security status or perceived stress on HEI-2020 total or component scores, although there were significant interactive effects for food security and perceived stress on total vegetable and total protein component scores. For the food insecure group, higher stress improved compliance with the Dietary Guidelines for Americans (DGAs) for the total protein score but worsened compliance with the DGAs for the total vegetable score.

While this study failed to report any significant associations between perceived stress and diet quality, it did reveal that food security moderates the influence of perceived stress on two components of the HEI-2020. Limited studies have explored the nature of associations between stress and diet quality among college students, and this study put forth evidence that the effects of perceived stress on diet quality can be moderated by food security, and therefore warrant further study. Furthermore, additional demographic factors, such as age or racial identity, should also be considered for how they may moderate the relationship between stress and diet in this population.

The aim of chapter 3 was to investigate whether or not a simple and individually modifiable intervention could improve the diet quality of college students from two large university campuses. A secondary aim was to evaluate the feasibility and acceptability of the intervention. Eligibility for participation required being 18 to 25 years of age, enrolled as a full-time student at the university, fluent in English, without medical conditions or allergies that would require modification of diet, without eating disorder symptoms, and with a diet not currently complying with dietary guidelines. Participants were contacted by phone on random days and asked to complete two separate interviewer-led, 24-hour recalls using the Automated Self-Administered 24-hour recall tool (ASA24), at baseline, week 4, and week 8. Participants also completed baseline and follow-up surveys that collected information on individual demographics, food security, perceived psychological stress, readiness to change, and intervention feasibility. Participants in the control group received information about the DGAs and were asked to read and consider the principles. Participants in the experimental group selected two of seven dietary change statements, each of which was intended to improve at least one component of diet quality, and these were printed into keychain tags and delivered to the participants with instructions to keep them on their person at all times. Results of the intervention reported no significance difference within or between the control and experimental groups at any time point for HEI-2020 total or component scores, with the exception of the control group's total vegetable score increasing from baseline to week 4, and returning to non-significance by week 8. Despite the non-significant findings, the majority of students who completed the feasibility survey reported satisfaction with the study intervention's ease and utility.

Effectiveness of Small Change Interventions

The aim of chapter 1's systematic review was to assess the efforts, methods, and effectiveness of intervention trials that employed ETL interventions among young adults. The majority of studies identified from this effort were RCTs, and among these, four studies used an implementation intentions approach that had participants write out a personalized, simple directive for how to improve a component of their diet, or were provided with this simple directive, and would carry it on their person throughout the study. Three of these 4 studies reported significant dietary behavior changes in the experimental versus control groups. The results reported from this systematic review were critical in constructing the intervention for the RCT conducted in chapter 3. Contrary to expectations, the intervention did not produce significant improvements to HEI-2020 or its component scores between the control and experimental groups. Furthermore, at the final assessment point of the study, HEI-2020 scores were 62.9 for the control group, and 63.4 for the experimental group, both of which are lower than the nationwide mean of 64.8±0.2.[41]

Despite chapter 3's evidence-based intervention, it did not effectively improve diet quality within the target population. These results conflict with studies conducted among young adults that reported significant improvement in at least one aspect of diet quality following a simple intervention prescribing simple dietary changes or prompts to encourage dietary change.[56,98–100] Even among college students, small-change interventions have produced significant improvements in diet quality. In one setting, a predominantly female (85.5%) cohort of students, ages 18-23, were asked to upload pictures of their meals along with a brief description of each meal for three days. Those in the experimental group were also asked to count how many red or orange vegetables they ate, and were then counseled to set a goal of eating at least one more on the following day. For both days where goals were set, the experimental group ate significantly more vegetables than the control group.[194] In an even simpler setting, college students (mean age = 22) were offered measured portions of available sugary or salty snack foods they had selected, then randomized to watch the same movie either with or without headphones. The students who wore headphones consumed a smaller percentage of the snack foods, compared to the students who did not have headphones, suggesting that headphone use limited attention or appetite for snacks, and these results controlled for food related behavioral problems, movie preference, and immersion experience.[195]

The discrepancy between the success of previous studies and the results of this dissertation's prescribed intervention are not entirely clear. Within this intervention, it is possible that the students chose dietary practices that they already consistently practiced, and as a result, there would not have been a noted improvement. Or it may be that the American college environment is a particularly demanding setting, and the length of time prescribed to carry the selected tags gave opportunity for distractions to reassert previous dietary patterns. Furthermore, the experimental group was not offered any element of education beyond what was written on the tags, and nutrition education among college students usually yields favorable improvements to diet.[196,197]

Structural Approaches to Diet Improvement

As a contrast to small change or personalized interventions, structural interventions attempt to change environmental settings, and therefore target a larger population all at once. Sometimes characterized as "top-down" approaches, structural interventions are devised and implemented by a small group in authority and intended for effect on the group within a designated sphere of influence, be it social, environmental, or otherwise.[198]

A structural approach to improving a population's health carries distinct advantages, often requiring a lower absolute cost on a per-person basis or simultaneously targeting numerous risk factors that contribute to health disparities. However, the complex nature of structural interventions means they also carry potential drawbacks and limitations. Compared to an RCT where results can be observed within a span of a few weeks after the intervention, structural interventions may require years or even decades before there are observable outcomes.[199] If not built upon an evidence-based framework, structural interventions may be ineffective or produce more harm than good, such as food taxes that create a heavier financial burden without providing meaningful improvement to population-level BMI.[200]

Despite their limitations, many structural approaches have reported success upon small and cost-effective interventions. When French fry portions were reduced by 20% at an on-campus college restaurant in Belgium, reports indicated that French fry intake decreased by 9.1%, plate waste decreased by 66.4%, and patrons reported neither a change in satiety or caloric compensation later in the day.[201] Arrangements to how foods are presented in dining halls, or the addition of informational tags, may result in elevated fruit and vegetable intake or increase consumer awareness and engagement.[202,203] It is important to remember that these interventions serve as permanent adjustments to their environmental sphere of influence, and carry impact on thousands of individuals, often repeatedly.

The successes and limitations of both small-change, personalized interventions and population-level structural interventions make it clear that researchers and healthcare practitioners should not place them at odds with one another. Though structural interventions are a more favored choice from a public health perspective, given their propensity for affecting entire populations, there is no reason to set aside smaller-scale interventions as ineffective or without purpose. These approaches are not independent from one another, and evidence suggests that individualized approaches are more feasible in certain settings, and can be used to inform more appropriate population-level interventions.[73,75]

Future Implications for Research

Assignment to either group for this dissertation's intervention did not result in improved HEI-2020 total or component scores, but the high rate of compliance and responses from study participants provide evidence that it was feasible. This contrast of feasibility and effectiveness presents an interesting dilemma for researchers. On the one hand, a treatment can be effective, but if participants are unwilling or feel unable to comply with that treatment's requirements, there will be no benefit derived from the intervention. On the other hand, a treatment can be highly engaging and easy to comply with, but if the intervention is ultimately ineffective, there is still no derived benefit. Designing an intervention among college students that can successfully improve diet-related behaviors clearly requires an intersection of both efficacy and feasibility. While this study was unable to accomplish that task, it does provide evidence for better practices that can be applied to future studies.

Future studies that include an element of selection or choice when attempting to improve diet quality in college students should carefully consider which choices are presented, and why. This dissertation gave all participants access to the same choices, independent of individual characteristics. A better approach in a follow-up study that again utilized dietary change statements would be to assess participant diet quality at baseline, calculate HEI-2020 component scores, and determine the poorest components of diet quality, individually. Then, these components would be presented to the participant for selection as part of the intervention.

Age, sex, race, food security, and perceived stress have all been independently studied to examine their impact on diet quality in college students, but additional studies need to be carefully designed and performed to evaluate moderating effects between these factors. As an example, age is associated with food insecurity, but that association may be moderated by a student's living conditions, proximity to family, or knowledge of food and nutrition. Closer examination of a student's personal conditions can help provide more detailed context for effective interventions, something that cannot be accomplished by overreliance on broad and immutable categories, such as sex or race.

Additionally, future simple dietary behavior interventions targeting college students should consider alternative activities that are not immediately related to nutrition, but still relate to the student experience, such as stress or time management. If non-diet factors such as perceived stress or minimal motivation for improving health are associated with diet quality, than improving diet quality may plausibly be accomplished by addressing those non-diet factors, when compared to passive control groups. Finally, researchers may need to strike a careful balance between low-intensity interventions that promote compliance and are tailored and guided in a way that still accomplishes the intended aim of improving dietary practices. This may be accomplished by more active involvement from the research team, where weekly reminders or messages are texted to students to encourage their engagement and simply remind them to participate.

The quandary of improving poor diet quality in college students begins by acknowledging the opportunities present within the challenges of college life. College is a time of progression and individual growth, a transition from youth into adulthood where learning practices of personal care should be esteemed just as much as learning practices of vocation. Reliance upon previous support systems may no longer be directly present, but this can be a stepping stone into greater independence.[25] The psychological maturity that allows for a more fixed expression of identity can also help bring about the development of healthy habits and behaviors.[26] Rather than shrinking under the burden of newfound responsibilities, such as care for personal health, college students can learn to thrive and build a greater sense of self-esteem that translates into success in their academic pursuits.[27]

There is a dire need to improve the diet quality of college students, as numerous studies across the United States have reported low HEI scores that are below the recommend score of 80.[40–42,171] Personal as well as environmental factors should be considered in designing interventions that improve diet quality, as well as student readiness to change, current demands of schedule, and the addition of simplistic educational elements. Simple and personalized approaches to improving diet quality can be an effective means of improving the health of college students, while also helping to establish habits and dietary patterns that will serve a lifetime.

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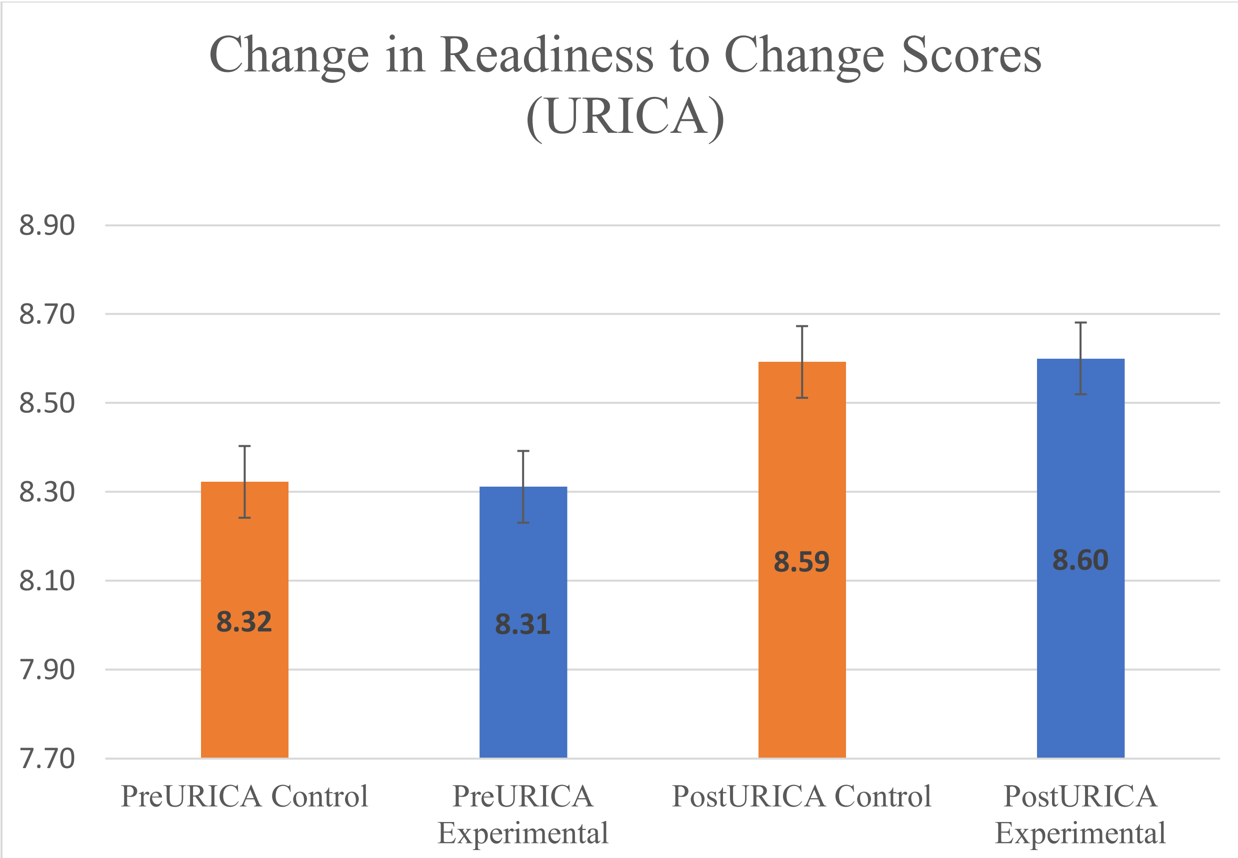
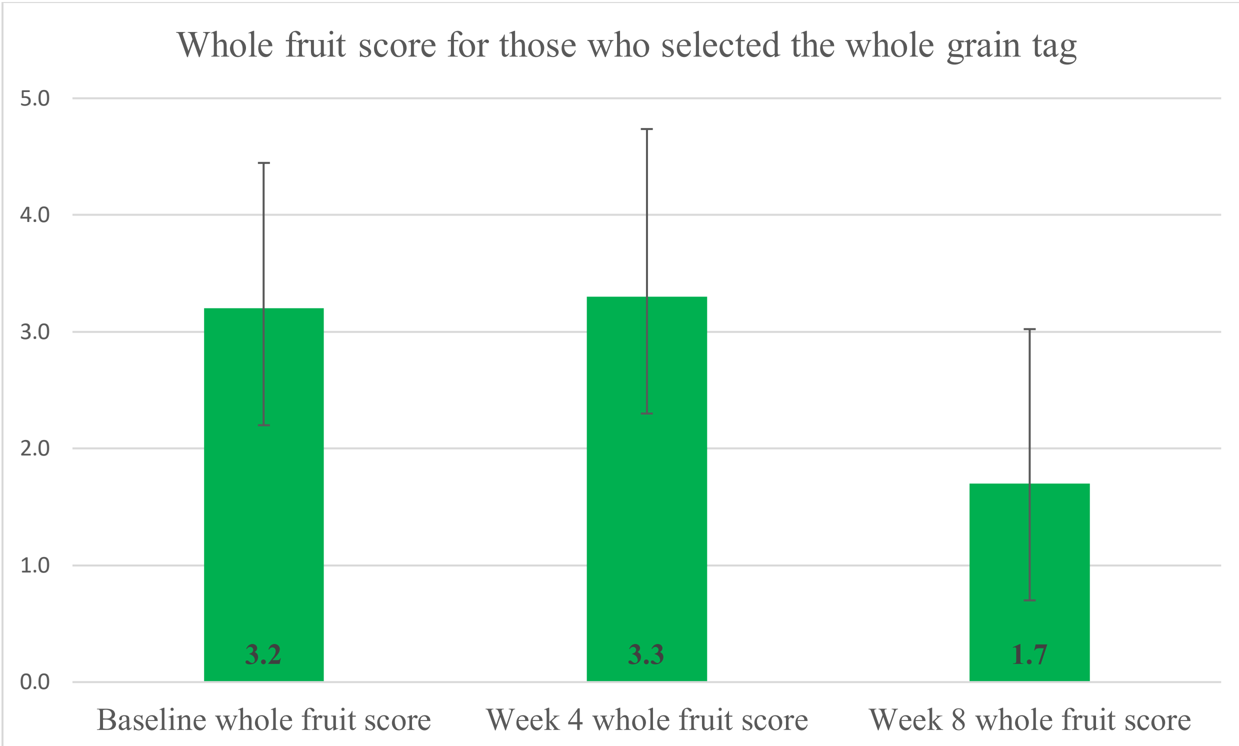
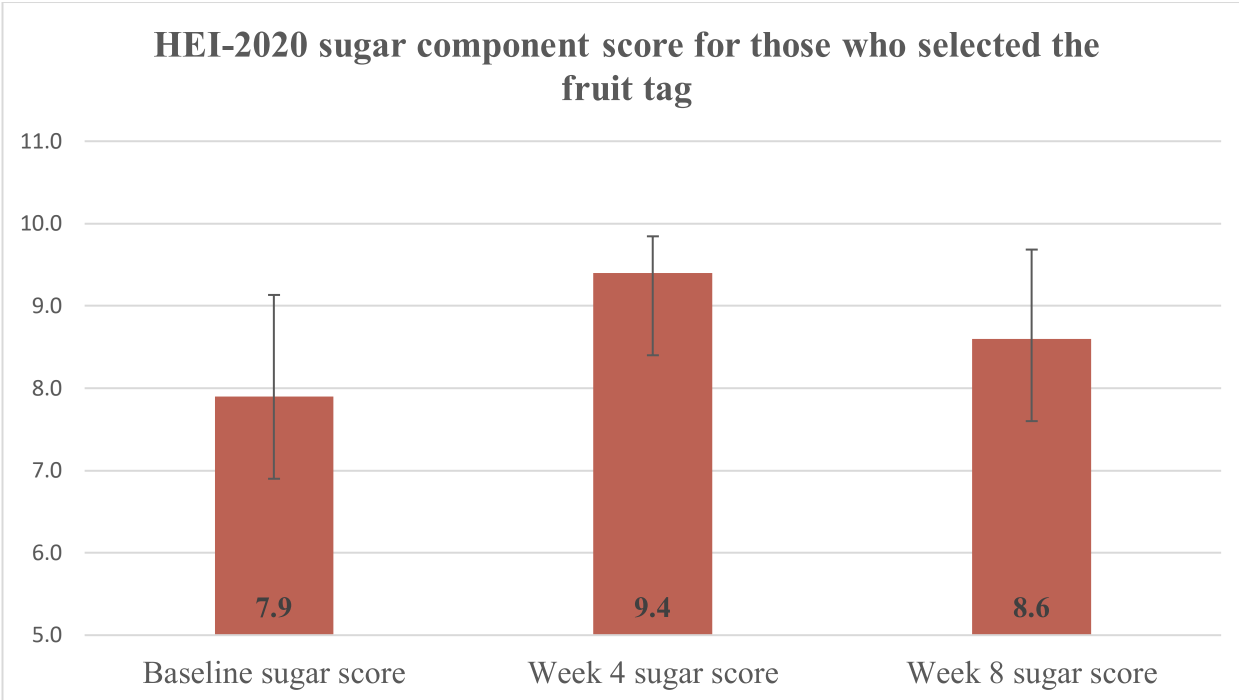
APPENDIX FIGURES



Appendix Figure 1 Chart display of URICA scores at baseline and study endpoint (week 8) in each group. In the total population, PreURICA score of 8.3±1.7 increased to 8.6±1.6 by week 8 ($p=0.041$), with no significant difference observed between groups. Abbreviations: PreURICA, Baseline University of Rhode Island Change



Appendix Figure 2 Chart display of HEI-2020 whole fruit component score across timepoints for participants within the experimental group who selected the whole grain tag. Scores significantly decreased from week 4 to week 8 (F=4.385, p=0.031). Abbreviations: HEI-2020, Healthy Eating Index 2020.



Appendix Figure 3 Chart display of HEI-2020 sugar component score across timepoints for participants within the experimental group who selected the fruit tag. Scores significantly increased from baseline to week 4 (F=5.019, p=0.013). Abbreviations: HEI-2020, Healthy Eating Index 2020.

APPENDIX TABLES

APPENDIX TABLE 1: Results of assigned intervention with intent-to-treat analysis on HEI-2020 total and component scores

HEI-2020 and Components	Baseline						Week 4						Week 8					
	Control			Experimental			Control			Experimental			Control			Experimental		
	Mean	Lower CI	Upper CI	Mean	Lower CI	Upper CI	Mean	Lower CI	Upper CI	Mean	Lower CI	Upper CI	Mean	Lower CI	Upper CI	Mean	Lower CI	Upper CI
Total Vegetables	3.31[1]	2.88	3.78	3.81	3.22	4.44	4.60[1]	3.83	5.00	4.14	3.55	4.77	3.57	3.05	4.12	4.42	3.74	5.00
Greens and Beans	3.46	2.23	4.73	4.69	3.34	5.00	4.66	3.34	5.00	4.94	4.22	5.00	4.25	2.35	5.00	4.95	4.27	5.00
Total Fruit	3.52	2.32	4.74	2.91	2.10	3.76	3.61	2.73	4.51	3.32	2.50	4.20	3.67	2.58	4.77	2.94	2.14	3.76
Whole Fruit	4.90	3.92	5.00	4.14	2.87	5.00	4.79	3.66	5.00	4.84	3.90	5.00	4.74	3.45	5.00	4.35	2.88	5.00
Whole Grains	3.21	2.40	4.05	2.98	2.06	3.90	3.44	2.44	4.41	2.62	1.66	3.61	2.86	2.02	3.72	3.43	2.25	4.66
Dairy	5.77	4.68	6.85	5.65	4.75	6.55	5.18	4.40	5.98	6.67	5.61	7.71	5.05	4.13	5.96	5.05	4.18	5.91
Total Protein	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00
Seafood and Plant Proteins	4.85	3.97	5.00	4.90	3.91	5.00	5.00	5.00	5.00	4.95	4.30	5.00	4.99	4.80	5.00	4.97	4.51	5.00
Fatty Acid Ratio	5.73	4.48	7.13	5.48	4.10	6.98	5.96	4.85	7.16	4.75	3.67	5.94	6.18	5.09	7.36	6.13	4.98	7.42
Sodium	2.30	1.03	3.57	0.59	0.00	1.78	2.13	0.78	3.43	1.63	0.44	2.75	2.63	1.43	3.84	1.57	0.17	2.96
Refined Grains	5.70	4.47	6.90	5.83	4.30	7.35	5.58	4.21	6.91	5.01	3.57	6.49	5.90	4.74	7.04	5.81	4.68	6.97
Saturated Fat	6.21	5.17	7.31	5.45	4.49	6.43	6.52	5.59	7.47	4.84	3.83	5.89	6.04	5.20	6.92	5.58	4.54	6.66
Added Sugar	8.22	7.46	8.96	8.63	7.82	9.42	9.01	8.26	9.73	9.23	8.61	9.90	8.69	7.88	9.45	9.34	8.58	10.00
Total HEI-2020	62.19	56.48	67.43	60.06	54.20	65.16	65.47	60.42	69.99	61.94	57.49	65.97	63.59	58.16	68.22	63.54	58.23	68.42

HEI-2020, Healthy Eating Index 2020; CI, Confidence Intervals

[1]Designates a significant difference where $p<0.05$

APPENDIX TABLE 2: Two-Way Repeated Measures ANOVA Using Simple Method HEI-2020 Total and Component Scores

HEI Component	Group	Baseline score		Week 4 score		Week 8 score		Time x Group Assignment		Time x Group Assignment (Adjusted to include PreURICA scores)	
		Mean	SD	Mean	SD	Mean	SD	F	p-value	F	p-value
Total Fruit Score (0-5)	Control	2.7	2.1	2.7	2.0	2.6	2.1	0.259	0.765	0.323	0.717
	Experimental	2.4	1.7	2.7	1.9	2.2	1.8				
Whole Fruit Score (0-5)	Control	3.0	2.2	2.6	2.2	2.7	2.2	1.501	0.226	1.653	0.198
	Experimental	2.9	2	3.2	2.1	2.4	2.2				
Total Vegetable Score (0-5)	Control	3.1	1.5	3.7	1.5	3.3	1.5	0.906	0.405	0.776	0.461
	Experimental	3.5	1.2	3.8	1.3	3.8	1.4				
Green Beans Score (0-5)	Control	2.2	2.1	2.5	2.1	2.1	2.2	0.359	0.694	0.306	0.732
	Experimental	3.0	2	3	2.2	3	2.1				
Total Protein Score (0-5)	Control	4.6	0.8	4.5	1	4.6	0.9	0.879	0.407	0.885	0.405
	Experimental	4.6	0.9	4.6	0.9	4.9	0.4				
Seafood and Protein Score (0-5)	Control	3.1	2.1	3.3	2.1	3.3	2.1	0.16	0.846	0.143	0.860
	Experimental	3.0	2	3.1	2.1	2.9	2.1				
Whole Grains Score (0-10)	Control	3.4	3.1	3.1	3.4	2.9	3.3	1.449	0.237	1.541	0.217
	Experimental	2.7	3.2	2.5	3	3.4	3.4				
Dairy Score (0-10)	Control	5.2	3.2	5.2	2.7	4.7	2.9	0.612	0.533	0.551	0.566
	Experimental	5.3	3.1	6	2.7	4.7	2.8				
Fatty Acid Score (0-10)	Control	6.1	3.6	6.1	3.2	6.2	3.4	0.171	0.841	0.160	0.850
	Experimental	5.9	3.5	5.3	3.1	6	3.1				
Refined Grains Score (0-10)	Control	5.3	3.6	5.1	3.8	5.3	3.3	0.371	0.688	0.299	0.740
	Experimental	5.6	3.6	5	3.8	5.8	3				
Sodium Score (0-10)	Control	3.2	3.1	3	3	3.5	3.1	0.368	0.684	0.313	0.723
	Experimental	2.1	2.3	2.5	2.8	2.8	2.7				

Sugar Score (0-10)	Control	7.8	2.3	8.3	2.3	8	2.5	0.332	0.708	0.382	0.674
	Experimental	8.2	2.5	9	1.5	8.8	2.1				
Saturated Fatty Acid Score (0-10)	Control	6.3	3.3	6.4	2.9	6.2	2.8	0.133	0.871	0.130	0.873
	Experimental	5.6	3	5.4	3.2	5.7	3.4				
HEI-2020 Total Score (0-100)	Control	55.9	15.4	56.4	13.8	55.3	14.1	0.259	0.770	0.232	0.790
	Experimental	54.7	12.3	56.0	12.7	56.5	14.4				

FDR, False Discovery Rate; HEI-2020, Healthy Eating Index 2020; PreURICA, Baseline University of Rhode Island Change Assessment; SD, Standard Deviation

[1]Q-values were calculated using Benjamin-Hochberg method, based on p-values adjusted to include PreURICA scores.

APPENDIX TABLE 3: Effect of group assignment and baseline readiness to change scores (PreURICA) as predictors of Healthy Eating Index-2020 scores at week 8

		Model 1					Model 2					Model 3				
	Variables	β	SE	95% CI (Lower/Upper)		P	β	SE	95% CI (Lower/Upper)		P	β	SE	95% CI (Lower/Upper)		P
Total Fruit Score	Age (years)	-0.171	0.113	-0.396	0.054	0.135	-0.177	0.120	-0.416	0.063	0.146	-0.178	0.121	-0.419	0.063	0.146
	Race	0.004	0.149	-0.293	0.300	0.980	0.006	0.151	-0.293	0.306	0.966	0.005	0.152	-0.296	0.307	0.972
	BMI (kg/m²)	0.028	0.047	-0.066	0.122	0.552	0.028	0.050	-0.072	0.127	0.584	0.027	0.051	-0.074	0.128	0.596
	PreURICA						0.033	0.125	-0.215	0.280	0.795	0.021	0.147	-0.271	0.314	0.885
	Treatment						-0.291	0.404	-1.093	0.511	0.473	-0.570	1.998	-4.537	3.397	0.776
	PreURICA x Treatment											0.034	0.236	-0.435	0.503	0.887
	R^2	0.026				0.465	0.033				0.677	0.033				0.790
Whole Fruit Score	Age (years)	-0.141	0.125	-0.390	0.107	0.262	-0.171	0.133	-0.435	0.093	0.201	-0.171	0.134	-0.437	0.095	0.205
	Race	0.032	0.165	-0.296	0.360	0.848	0.031	0.166	-0.299	0.362	0.850	0.031	0.167	-0.301	0.364	0.851
	BMI (kg/m²)	-0.024	0.052	-0.128	0.079	0.641	-0.035	0.055	-0.145	0.075	0.530	-0.035	0.056	-0.146	0.076	0.535
	PreURICA						0.108	0.138	-0.165	0.381	0.434	0.109	0.163	-0.215	0.432	0.506
	Treatment						-0.230	0.446	-1.115	0.655	0.607	-0.218	2.204	-4.595	4.160	0.922
	PreURICA x Treatment											-0.001	0.261	-0.519	0.516	0.996
	R^2	0.017				0.659	0.026				0.772	0.026				0.867
Total Vegetable Score	Age (years)	0.022	0.086	-0.149	0.193	0.799	0.049	0.090	-0.129	0.227	0.587	0.046	0.090	-0.134	0.225	0.615
	Race	0.059	0.114	-0.167	0.285	0.603	0.056	0.112	-0.167	0.279	0.620	0.053	0.113	-0.171	0.277	0.637
	BMI (kg/m²)	0.005	0.036	-0.067	0.076	0.895	0.012	0.037	-0.062	0.087	0.745	0.011	0.038	-0.064	0.086	0.780
	PreURICA						-0.113	0.093	-0.297	0.072	0.229	-0.140	0.110	-0.358	0.078	0.206
	Treatment						0.540	0.301	-0.057	1.137	0.076	-0.147	1.485	-3.096	2.803	0.922
	PreURICA x Treatment											0.083	0.176	-0.266	0.432	0.638
	R^2	0.005				0.930	0.055				0.374	0.057				0.474

	Variables	Model 1					Model 2					Model 3				
		β	SE	95% CI (Lower/Upper)		P	β	SE	95% CI (Lower/Upper)		P	β	SE	95% CI (Lower/Upper)		P
Green Beans Score	Age (years)	0.094	0.126	-0.157	0.345	0.459	0.067	0.132	-0.196	0.329	0.615	0.058	0.133	-0.206	0.321	0.664
	Race	0.178	0.167	-0.153	0.509	0.289	0.166	0.165	-0.163	0.494	0.319	0.159	0.166	-0.170	0.488	0.340
	BMI (kg/m^2)	-0.012	0.053	-0.117	0.093	0.819	-0.028	0.055	-0.138	0.082	0.613	-0.033	0.055	-0.143	0.078	0.559
	PreURICA						0.051	0.137	-0.221	0.322	0.712	-0.026	0.161	-0.346	0.294	0.874
	Treatment						0.851	0.443	-0.029	1.731	0.058	-1.070	2.182	-5.404	3.264	0.625
	PreURICA x Treatment											0.232	0.258	-0.280	0.744	0.371
	R^2		0.022			0.545		0.060			0.321		0.068			0.355
Total Protein Score	Age (years)	0.042	0.041	-0.039	0.123	0.301	0.031	0.043	-0.054	0.116	0.467	0.035	0.043	-0.051	0.120	0.422
	Race	-0.043	0.054	-0.150	0.064	0.427	-0.047	0.054	-0.153	0.060	0.385	-0.044	0.054	-0.151	0.062	0.412
	BMI (kg/m^2)	0.015	0.017	-0.019	0.049	0.371	0.009	0.018	-0.026	0.045	0.599	0.011	0.018	-0.025	0.047	0.537
	PreURICA						0.025	0.044	-0.063	0.114	0.568	0.054	0.052	-0.050	0.157	0.305
	Treatment						0.246	0.144	-0.040	0.531	0.091	0.960	0.706	-0.443	2.362	0.178
	PreURICA x Treatment											-0.086	0.084	-0.252	0.080	0.305
	R^2		0.024			0.505		0.056			0.362		0.067			0.368
Seafood and Protein Score	Age (years)	0.220	0.116	-0.011	0.452	0.061	0.205	0.124	-0.040	0.451	0.100	0.221	0.123	-0.022	0.465	0.074
	Race	-0.183	0.154	-0.488	0.122	0.237	-0.181	0.155	-0.488	0.126	0.246	-0.168	0.153	-0.472	0.136	0.275
	BMI (kg/m^2)	-0.103	0.049	-0.199	-0.006	**0.037**	-0.107	0.052	-0.209	-0.004	0.041	-0.099	0.051	-0.200	0.003	0.058
	PreURICA						0.065	0.128	-0.190	0.319	0.615	0.203	0.149	-0.093	0.499	0.176
	Treatment						-0.319	0.415	-1.142	0.504	0.443	3.170	2.017	-0.836	7.176	0.119
	PreURICA x Treatment											-0.421	0.238	-0.895	0.052	0.081
	R^2		0.080			**0.048**		0.088			0.120		0.118			0.066

	Variables	Model 1					Model 2					Model 3				
		β	SE	95% CI (Lower/Upper)		P	β	SE	95% CI (Lower/Upper)		P	β	SE	95% CI (Lower/Upper)		P
Whole Grains Score	Age (years)	-0.044	0.194	-0.430	0.342	0.821	-0.121	0.206	-0.529	0.288	0.558	-0.120	0.207	-0.532	0.292	0.564
	Race	0.128	0.256	-0.381	0.637	0.620	0.115	0.257	-0.396	0.626	0.656	0.116	0.259	-0.399	0.630	0.656
	BMI (kg/m^2)	0.048	0.081	-0.113	0.209	0.558	0.015	0.086	-0.156	0.185	0.866	0.015	0.087	-0.157	0.187	0.864
	PreURICA						0.232	0.213	-0.191	0.655	0.279	0.238	0.252	-0.262	0.738	0.347
	Treatment						0.454	0.689	-0.915	1.823	0.512	0.612	3.410	-6.161	7.385	0.858
	PreURICA x Treatment											-0.019	0.403	-0.820	0.782	0.962
	R^2		0.006			0.892		0.023			0.826		0.023			0.905
Dairy Score	Age (years)	0.014	0.165	-0.315	0.342	0.935	-0.059	0.175	-0.406	0.288	0.737	-0.034	0.173	-0.377	0.309	0.846
	Race	0.429	0.218	-0.005	0.862	0.052	0.423	0.219	-0.011	0.857	0.056	0.443	0.216	0.014	0.871	0.043
	BMI (kg/m^2)	-0.005	0.069	-0.142	0.132	0.945	-0.033	0.073	-0.178	0.112	0.652	-0.020	0.072	-0.163	0.123	0.782
	PreURICA						0.243	0.181	-0.116	0.603	0.183	0.460	0.210	0.043	0.876	0.031
	Treatment						-0.101	0.586	-1.266	1.063	0.863	5.358	2.841	-0.284	11.000	0.062
	PreURICA x Treatment											-0.659	0.336	-1.326	0.008	0.053
	R^2		0.042			0.255		0.061			0.316		0.098			0.137
Fatty Acid Score	Age (years)	0.343	0.187	-0.027	0.714	0.069	0.384	0.199	-0.011	0.779	0.057	0.368	0.199	-0.028	0.763	0.068
	Race	-0.038	0.247	-0.527	0.451	0.878	-0.031	0.249	-0.525	0.463	0.902	-0.043	0.249	-0.537	0.451	0.863
	BMI (kg/m^2)	0.057	0.078	-0.098	0.212	0.465	0.075	0.083	-0.090	0.240	0.368	0.067	0.083	-0.099	0.232	0.424
	PreURICA						-0.118	0.206	-0.527	0.291	0.567	-0.255	0.242	-0.735	0.226	0.296
	Treatment						-0.303	0.667	-1.626	1.021	0.651	-3.736	3.277	-10.245	2.772	0.257
	PreURICA x Treatment											0.415	0.387	-0.355	1.184	0.287
	R^2		0.043			0.241		0.048			0.458		0.060			0.445

	Variables	Model 1					Model 2					Model 3				
		β	SE	95% CI (Lower/Upper)		P	β	SE	95% CI (Lower/Upper)		P	β	SE	95% CI (Lower/Upper)		P
Refined Grains Score	Age (years)	0.022	0.185	-0.345	0.390	0.905	-0.054	0.196	-0.443	0.334	0.782	-0.050	0.197	-0.441	0.342	0.802
	Race	0.170	0.244	-0.315	0.655	0.489	0.157	0.245	-0.329	0.643	0.523	0.161	0.246	-0.329	0.650	0.516
	BMI (kg/m^2)	-0.057	0.077	-0.210	0.096	0.463	-0.090	0.082	-0.252	0.072	0.272	-0.088	0.082	-0.252	0.076	0.289
	PreURICA						0.230	0.203	-0.173	0.632	0.260	0.270	0.240	-0.206	0.745	0.263
	Treatment						0.478	0.656	-0.825	1.781	0.469	1.477	3.244	-4.966	7.921	0.650
	PreURICA x Treatment											-0.121	0.384	-0.882	0.641	0.754
	R^2		0.011			0.791		0.029			0.736		0.030			0.827
Sodium Score	Age (years)	0.030	0.172	-0.312	0.372	0.862	0.068	0.183	-0.295	0.431	0.711	0.057	0.184	-0.308	0.423	0.755
	Race	0.091	0.228	-0.361	0.543	0.689	0.101	0.229	-0.353	0.556	0.659	0.093	0.230	-0.363	0.549	0.686
	BMI (kg/m^2)	-0.039	0.072	-0.182	0.104	0.590	-0.020	0.076	-0.172	0.131	0.790	-0.026	0.077	-0.178	0.127	0.738
	PreURICA						-0.099	0.189	-0.475	0.278	0.603	-0.188	0.223	-0.632	0.255	0.402
	Treatment						-0.572	0.613	-1.790	0.646	0.354	-2.827	3.025	-8.835	3.180	0.352
	PreURICA x Treatment											0.272	0.358	-0.438	0.983	0.448
	R^2		0.005			0.921		0.017			0.903		0.023			0.904
Sugar Score	Age (years)	0.051	0.136	-0.218	0.321	0.706	0.024	0.143	-0.260	0.308	0.869	0.036	0.143	-0.249	0.320	0.804
	Race	-0.189	0.179	-0.545	0.167	0.295	-0.200	0.179	-0.555	0.156	0.267	-0.190	0.179	-0.546	0.165	0.290
	BMI (kg/m^2)	0.029	0.057	-0.083	0.142	0.605	0.014	0.060	-0.105	0.133	0.815	0.020	0.060	-0.099	0.139	0.737
	PreURICA						0.058	0.148	-0.236	0.352	0.697	0.160	0.174	-0.185	0.506	0.359
	Treatment						0.740	0.479	-0.213	1.692	0.126	3.327	2.356	-1.353	8.006	0.161
	PreURICA x Treatment											-0.312	0.279	-0.866	0.241	0.265
	R^2		0.014			0.709		0.040			0.571		0.053			0.531

	Variables	Model 1					Model 2					Model 3				
		β	SE	95% CI (Lower/Upper)		P	β	SE	95% CI (Lower/Upper)		P	β	SE	95% CI (Lower/Upper)		P
Saturated Fatty Acid Score	Age (years)	0.186	0.181	-0.174	0.545	0.308	0.185	0.193	-0.198	0.568	0.340	0.181	0.194	-0.205	0.567	0.355
	Race	-0.182	0.239	-0.656	0.292	0.449	-0.178	0.241	-0.657	0.301	0.462	-0.182	0.243	-0.664	0.301	0.456
	BMI (kg/m^2)	-0.015	0.076	-0.165	0.135	0.843	-0.013	0.081	-0.173	0.146	0.868	-0.016	0.081	-0.177	0.146	0.848
	PreURICA						0.016	0.200	-0.380	0.413	0.935	-0.020	0.236	-0.489	0.449	0.932
	Treatment						-0.317	0.647	-1.601	0.968	0.626	-1.237	3.198	-7.588	5.114	0.700
	PreURICA x Treatment											0.111	0.378	-0.640	0.862	0.769
	R^2	0.014				0.712	0.017				0.900	0.018				0.946
HEI-2020 Total Score	Age (years)	0.669	0.820	-0.959	2.297	0.417	0.430	0.872	-1.300	2.161	0.623	0.449	0.878	-1.296	2.193	0.611
	Race	0.456	1.082	-1.693	2.604	0.675	0.420	1.090	-1.745	2.584	0.701	0.434	1.097	-1.744	2.612	0.693
	BMI (kg/m^2)	-0.072	0.342	-0.752	0.608	0.834	-0.174	0.364	-0.896	0.548	0.633	-0.165	0.367	-0.894	0.564	0.655
	PreURICA						0.731	0.902	-1.062	2.523	0.420	0.886	1.067	-1.232	3.004	0.408
	Treatment						1.175	2.921	-4.626	6.976	0.688	5.099	14.445	-23.591	33.789	0.725
	PreURICA x Treatment											-0.474	1.708	-3.866	2.918	0.782
	R^2	0.011				0.789	0.019				0.872	0.020				0.929

BMI, Body Mass Index; CI, Confidence Interval; HEI-2020, Healthy Eating Index 2020; PreURICA, Baseline University of Rhode Island Change Assessment Scale; SE, Standard Error.