Advances in Nutrition 15 (2024) 100131

American Society for Nutrition
Excellence in Nutrition Research and Practice

Advances in Nutrition
AN INTERNATIONAL REVIEW JOURNAL
journal homepage: https://advances.nutrition.org/

Review

Methods for Assessing Health Outcomes Associated with Food Insecurity in the United States College Student Population: A Narrative Review☆

Marcela D. Radtke [1], Francene M. Steinberg [2], Rachel E. Scherr [3,4,*]

[1] Propel Postdoctoral Fellow, Department of Epidemiology and Population Health, Stanford School of Medicine, Stanford University, Palo Alto, CA, USA 94305; [2] Department of Nutrition, University of California, Davis, Davis, CA, USA, 95616; [3] Family, Interiors, Nutrition & Apparel Department, San Francisco State University, 1600 Holloway Avenue, San Francisco, CA, USA, 94132; [4] Scherr Nutrition Science Consulting, San Francisco, CA, 94115

ABSTRACT

In the United States, college students experience disproportionate food insecurity (FI) rates compared to the national prevalence. The experience of acute and chronic FI has been associated with negative physical and mental health outcomes in this population. This narrative review aims to summarize the current methodologies for assessing health outcomes associated with the experience of FI in college students in the United States. To date, assessing the health outcomes of FI has predominately consisted of subjective assessments, such as self-reported measures of dietary intake, perceived health status, stress, depression, anxiety, and sleep behaviors. This review, along with the emergence of FI as an international public health concern, establishes the need for novel, innovative, and objective biomarkers to evaluate the short- and long-term impacts of FI on physical and mental health outcomes in college students. The inclusion of objective biomarkers will further elucidate the relationship between FI and a multitude of health outcomes to better inform strategies for reducing the pervasiveness of FI in the United States college student population.

Keywords: food insecurity, dietary intake, diet quality, depression, anxiety, stress, cognition, college students, university students

Statements of significance

This review highlights the assessment tools used to evaluate the physiological and cognitive health outcomes associated with the experience of food insecurity in college students and confirms the need for objective biomarkers to expand the generalizability of findings and develop effective interventions aimed at improving food security status.

Introduction

College students are disproportionately impacted by food insecurity (FI), with an estimated 40% of college students in the United States reporting a reduced quality or quantity diet, compared to the national prevalence of 10.2% [1,2]. Because of the underlying economic pressures of higher education, including the expensive cost of tuition and inflated cost of living in proximity to a college campus, the newfound autonomy over dietary choices and purchasing behaviors, and often perpetuated by limited nutrition knowledge and financial literacy, college students are at an increased risk for experiencing FI [3]. Emerging concerns regarding the inordinate prevalence of FI in college students have provided the impetus to explore the

Abbreviations: BRIEF-2, behavior rating inventory of executive function-2; DASS-21, depression anxiety and stress scales – 21-item short form; FI, food insecurity; FS, food secure; FSS, food security status; FSSM, food security survey module.

☆ Present address for MDR: Department of Epidemiology and Population Health, Stanford University School of Medicine, Stanford, CA 93405.

* Corresponding author. *E-mail address:* rachel@scherrnutritionscience.com (R.E. Scherr).

https://doi.org/10.1016/j.advnut.2023.10.004
Received 5 April 2023; Received in revised form 3 October 2023; Accepted 12 October 2023; Available online 21 October 2023

physiological, psychosocial, and cognitive impacts associated with acute and chronic FI in this population [4,5].

FI, as defined by the USDA, is the inability to maintain or acquire adequate food, which may result in disrupted eating patterns and decreased nutrient intake [6]. Food security status (FSS) is predominately evaluated using the validated USDA Food Security Survey Module (FSSM), which can screen for risk of FI using a 2-item screener (Hunger Vital Sign) or assess FSS at the individual or household level with the 6, 10, or 18 question version [7]. The Hunger Vital Sign was designed to serve as a screening tool to identify individuals and households at risk for experiencing FI but does not determine the severity of FI through the classification of high, marginal, low, and very low FFS [8]. Additional FI assessment methods, often adapted from the USDA FSSM to be utilized in specific populations, such as low- or middle-income countries, are utilized less frequently in the United States [9,10]. An additional emphasis has been placed on the inclusion of nutrition security to address not only the underconsumption of essential nutrients but also the juxtaposition of overconsuming energy-dense, nutrient-poor foods, leading to an increased risk for nutrient deficiencies in conjunction with chronic disease development [11].

To date, a majority of studies evaluating the impacts of FI on health-related outcomes in college students utilize subjective measures through self-report because of the reduced researcher and participant burden; however, self-reported assessments of health outcomes are prone to systematic selection and information biases [12,13]. Although larger sample sizes are more feasible in cross-sectional and observational studies, which tends to improve the generalizability of the findings with a more diverse and robust population, this study design limits causal inferences. Additionally, inducing FI for research purposes would be considered unethical, as food is considered a basic human right, resulting in a dearth of randomized controlled trials to elucidate the cause-and-effect relationship of FI on health outcomes [14,15].

Assessing the mechanisms involved in developing negative health outcomes associated with FI is essential to establish sustainable and effective intervention strategies [16]. The reduction in either the quality or quantity of food in the diet may decrease the intake of macronutrients, vitamins, and minerals that are essential in regulating metabolic processes, subsequently increasing risk of adverse physical or mental health outcomes [17]. Conversely, a reduced quality diet may also be associated with the increased consumption of ultra-processed and fast foods that contribute to increases in calories, total and saturated fats, added sugars, and sodium, ultimately contributing to weight gain, hypertension, and other chronic disease risk factors [17,18]. Ultra-processed and fast foods are sold in large quantities, often multiple servings in a single meal or package, at low cost [19], which is economically favorable for individuals experiencing FI [20].

This narrative review provides an overview of the methodologies implemented in recent research exploring the relationship between FI and physiological and cognitive health outcomes in college students. The predominant use of self-reported and subjective health status measures demonstrates the need for additional research using objective biomarkers to understand further the impact of acute and chronic FI on health outcomes in this population. As FI rates are significantly elevated in the United States college student population, this review urges a call to action for strategic policies and resources aimed at increasing FFS among college students, with the goal of improving physical and mental health outcomes.

Methods

This narrative review of relevant research features an overview of the assessment tools used to evaluate the physical and mental health outcomes associated with the experience of FI in college students. The literature published within the last 10 y (January 1, 2013–August 31, 2023) was systematically searched using 3 databases: PubMed, Google Scholar, and Web of Science, using targeted inclusion criteria identified apriori. With the implementation of the USDA FSSM being administered for the first time in the 1996 census, literature focusing on FI prevalence and health outcomes in the college student population has only been recently explored within the last decade. Inclusion criteria consisted of studies conducted in the United States in 2- or 4-y institutions and graduate and professional schools. Articles were excluded if FFS was classified using an assessment tool other than the 6, 10, or 18-item USDA FSSM. Studies that used the 2-item screener (Hunger Vital Sign) were not included in this analysis, as this tool only assesses the potential risk of FI, not an affirmative classification. Assessment tools for physiological, mental, and cognitive health must have utilized a previously validated measurement tool to assess 1 or more identified health outcomes, therefore excluding qualitative research studies using focus groups or interview-based research methodologies. An overview of the assessment tools implemented in the recent literature on FI and health outcomes in the college student population is provided in Figure 1.

The initial literature search was performed in December 2022, with a gap search performed in August 2023 to ensure all relevant literature was included. Search terms for the title and abstract review included “Food Security,” “Food Insecurity,” “College,” “University,” “Health,” “Physical Health,” “Mental Health,” “Cognitive Health,” and “Cognition,” among other keywords (Supplemental Table 1). Using the Covidence literature search platform, 3615 articles were identified based on specified search terms, following the removal of duplicates (n = 764) [21]. Screening was performed by 1 of the authors (MDR), where a total of 123 articles were identified for full-text review. Articles identified as potential for inclusion were reviewed (by MDR and RES) independently, with 59 articles meeting the inclusion criteria and included in this review. Any discrepancies were discussed prior to consensus. The following data were extracted by (MDR) and reviewed for extraction accuracy by (RES): sample size, participant characteristics, version of the USDA FSSM used to assess FSS, health outcomes of interest, a validated tool used to measure physiological, psychological, and cognitive health and main outcomes. Figure 2 details the article selection process using a PRISMA diagram.

FI and general health

The majority of research studies exploring FI and physiological health outcomes in college students are cross-sectional study designs that implement a variety of questionnaires to assess various

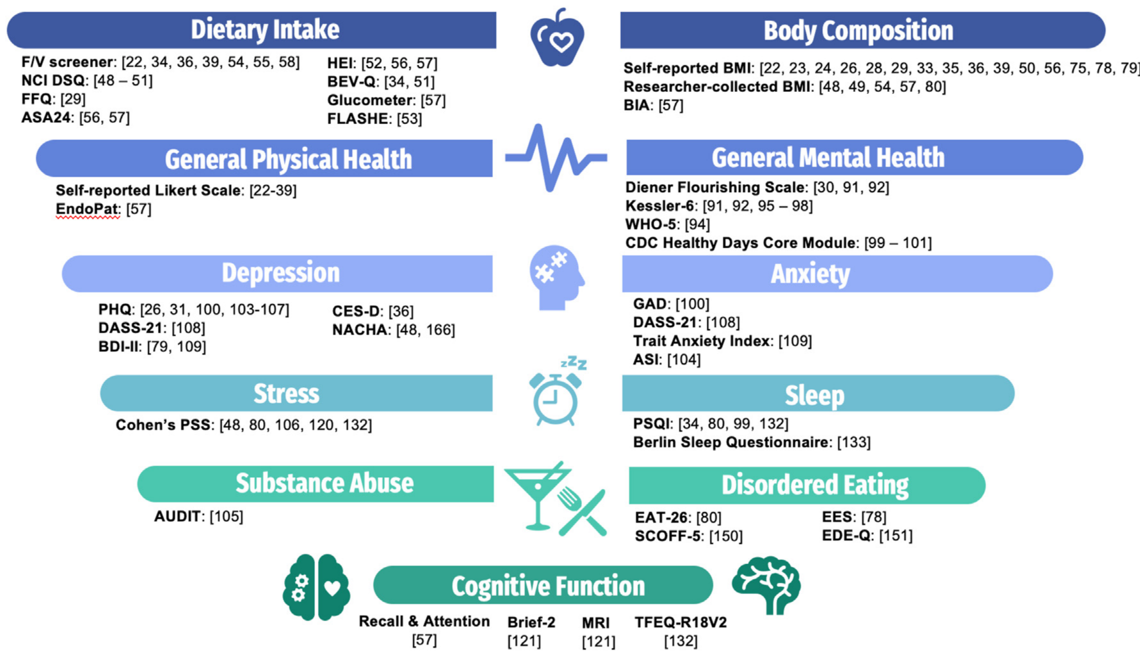

Figure 1. Assessment tools used to evaluate the physiological, psychosocial, and cognitive outcomes associated with the experience of food insecurity in the college student population. The bracketed numbers correspond with the literature published from 2013–2023 that included the corresponding health outcomes.

components of health. Self-rated health status is frequently assessed using a Likert scale ranking of excellent, good, fair, or poor [22–39]. Compared to food secure (FS) peers, students experiencing FI had significantly poorer overall general health rankings [22–39] (Table 1).

Research validating subjective measures of self-reported health status with objective biomarkers of health has reported conflicting results, such that some studies have observed inconsistencies and attenuation biases, with respondents underreporting health or disease burden [40], and others have found convergence between self-report and health outcomes [41]. To better understand the mechanisms causing health outcomes in the experience of FI, objective clinical and subclinical biomarkers are needed. The implementation of novel biomarkers in this emerging adult population may elucidate the role of FI on cardiac function [42], systemic inflammation [43], and body composition [44] to promote early detection and treatment of FI-related chronic disease development [45] into older adulthood.

FI and dietary intake

Changes in dietary intake are the first primary outcome observed in acute or chronic FI. The experience of FI may result in the physiological expression of undernutrition [46], overnutrition [47], or a combination of the 2 (Table 1).

FI and undernutrition

FI may be characterized by the reduction in total calorie intake, as well as specific nutrient deficiencies and inadequacies due to the underconsumption of diverse foods in the diet. The experience of FI is negatively associated with structured daily mealtimes, such as skipping breakfast or consuming only 1 meal/d [48]. College students who experience FI are more likely to report decreased intake of fruits and vegetables, which may result in inadequate fiber intake and a multitude of vitamins and minerals [22,29,39,48–55]. In the college student population, research exploring the relationship between FI and dietary intake has only consisted of subjective dietary and beverage assessment methods, such as Food Frequency Questionnaires (FFQs) [29], National Cancer Institute (NCI) Dietary Screener Questionnaire [48–51], Automated Self-Administered 24-h Dietary Assessment Tool [56,57], All Day Fruit and Vegetable Screener [34], the Food Intention Scale in the FLASHE (Family Life, Activity, Sun, Health, and Eating) survey [53], Healthy Eating Index scores [52,57], renditions of a self-reported fruit and vegetable intake questionnaire [22,36,54,55,58], and the Beverage Intake Questionnaire-15 [34,51]. A recent study assessing dietary intake and FI in the college student population used the Nutrition Data System for Research, which is currently referenced as the gold-standard for dietary intake data collection in free-living populations [59,60], but dietary changes resulting from differences by FSS were not reported [61].

Specific nutrients can be measured objectively to determine if an individual experiencing FI is nutrient deficient; however, such assessment methods are invasive and require plasma, serum, or tissue samples to extrapolate nutrient concentrations. These methods have been used to quantify nutrients of concern, such as folate, iron (ferritin and transferrin), copper, retinol, and zinc, in children, adolescents, and older adult populations [62,63]; however, objective measures of nutrient status have yet to be explored in college student populations experiencing FI. Innovative, noninvasive measures of nutrient status may be used to assess nutrient adequacy, including sensor-based technologies to detect sound and movement associated with eating patterns [64],

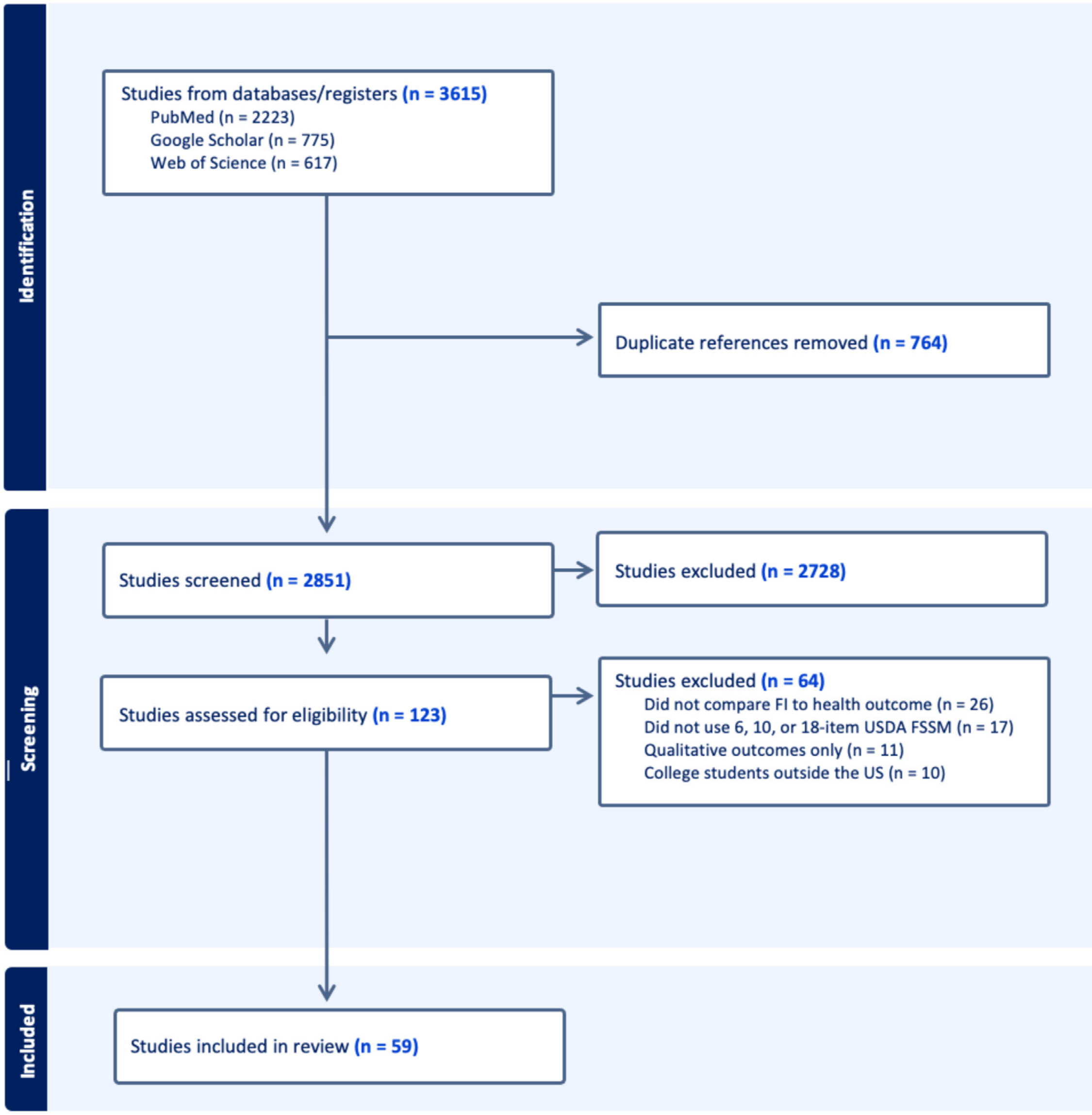

Figure 2. PRISMA diagram detailing the literature search selection process.

wearable image-based devices to capture dietary intake [65], and spectroscopy-based measurements to measure nutrients in the skin and tissue [66], among other emerging assessments [61,67,68].

Novel objective measures of dietary intake also include relative changes to the microbiome. Exploration into the role of FI on gut microbiome composition has been a topic of interest in the college student population, as the microbiome directly influences nutritional status [69,70]. Emerging evidence supports differences in the abundance and diversity of microbiota and metabolites by FSS; however, the physiological implication of these microbial changes is unknown [69]. Accounting for the challenges with obtaining fecal samples from college students, the use of improved collection and sequencing technologies, such as ingestible sampling devices or passive monitoring by smart toilets, may improve future research on the impact of FI on microbial imbalances [70,71].

FI and overnutrition

Encompassed with the definition of the double burden of malnutrition, the experience of overnutrition may still be accompanied by undernutrition or micronutrient deficiencies, as high-calorie intake may result in the underconsumption of essential vitamins and minerals [72–74]. Weight status, as it relates to nutritional adequacy, is often overlooked, as it is presumed that being overweight or obese corresponds to overnutrition of all nutrients [73]. In the experience of FI, a strategy for satiation is to consume calorically dense foods, thus often exceeding nutrient recommendations for added sugars, fat, and sodium, leading to an increased risk for overweight and obesity [22,25,28,29,33,39,49,50,75]. To assess the role of FI on body composition in college students, height and weight, along with abdominal and waist circumference, are either self-reported or collected by a trained researcher. Self-reported BMI (in

Table 1
Included studies published within the years 2013–2023 examining the relationship between food insecurity and physiological health outcomes in college students in the United States

Citation	Sample size (n)	Participant characteristics	USDA FSSM version	Health outcomes	Assessment tool	Outcomes associated with FI
Patton-Lopez et al., 2014 [37]	354	Western Oregon University Female: 72.9% Latinx: 8.2% FI: 58.8%	6-item	1. General health	1. Self-reported description of general health	1. ↓ General health
Bruening et al., 2016 [54]	209	Arizona State University Female: 62% Latinx: 27% FI: 32%	6-item	1. Body composition 2. F/V intake	1. Anthropometrics: BMI collected by a trained researcher 2. Self-reported weekly serving	1. No Δ in BMI 2. No Δ in F/V intake
Mirabitur et al., 2016 [55]	514	University of Michigan Female: 72.2% Underrepresented minorities: 15.8% FI: 41.5%	6-item	1. F/V intake	1. 2-item screener validated against serum carotenoids	1. ↓ F/V
Knol et al., 2017 [23]	351	University of Alabama Female: 72.4% Latinx: 8% FI: 37.6%	10-item	1. Body composition 2. General health	1. Anthropometrics: self-reported BMI 2. Self-reported description of general health	1. No Δ in BMI 2. ↓ General health
Bruening et.al., 2018 [48]	1138	Multiple Universities in Arizona Female: 65% Non-White: 49% FI: 32.8%	6-item	1. Body composition 2. Eating behaviors	1. Anthropometrics: BMI collected by a trained researcher 2. NCI 26-item DSQ	1. No Δ in BMI 2. ↓ Diet quality
Hagedorn et al., 2018 [38]	716	West Virginia University Female: 71.0% Non-White: 12.7% FI: 36.6%	10-item	1. General health	1. Self-reported description of general health	1. ↓ General health
McArthur et al., 2018 [24]	1093	Appalachian State University Female: 68.4% Non-White: 8.3% FI: 46.2%	10-item	1. Body composition 2. General health	1. Anthropometrics: self-reported BMI 2. Self-reported description of general health	1. ↑ BMI 2. ↓ General health
McArthur et al., 2018 [25]	456	Appalachian State University Female: 72.7% Non-White: 17.5% FI: 21.5%	10-item	1. General health	1. Self-reported description of general health	1. ↓ General health
Payne-Sturges et al., 2018 [26]	237	University of Maryland Female: 81% Non-White: 51% FI: 15%	18-item	1. Body composition 2. General health	1. Anthropometrics: self-reported height and weight 2. Self-reported description of general health	1. No results reported 2. ↓ General health

(*continued on next page*)

Table 1 (*continued*)

Citation	Sample size (n)	Participant characteristics	USDA FSSM version	Health outcomes	Assessment tool	Outcomes associated with FI
El Zein et al., 2019 [80]	855	8 United States Universities (University of Florida, University of Maine, University of Tennessee, Auburn University, South Dakota State University, Kansas State University, Syracuse University, and West Virginia University Female: 68.8% Non-White: 37.6% FI: 19%	10-item	1. Body composition	1. Anthropometrics: BMI and waist circumference collected by a trained researcher	1. No Δ in BMI or waist circumference
Leung et al, 2019 [50]	851	University of Michigan Female: 52.3% Non-White: 39.4% FI: 31.3%	10-item	1. Body composition 2. Dietary intake	1. Anthropometrics: self-reported BMI 2. NCI 26-item DSQ	1. ↑ BMI in very low FSS only 2. ↓ F/V; ↓ Whole-grains; ↓ fiber; ↑ added sugars; ↑ SSB
Martinez et al., 2019 [22]	8705	UC campuses (UC Berkeley, UC Davis, UC San Francisco, UC Riverside, UC Merced, UC San Diego, UC Santa Cruz, UC Santa Barbara, UC Los Angeles, UC Irvine) Female: 67% Non-White: 66% FI: 39.5%	6-item	1. F/V intake 2. Body composition 3. General health	1. Self-reported daily servings 2. Anthropometrics: self-reported BMI 3. Self-reported description of general health	1. ↓ Daily servings of F/V 2. ↑ BMI 3. ↓ General health
Soldavini et al., 2019 [28]	4819	University of North Carolina at Chapel Hill Female: 72% Non-White: 26.7% FI: 39.5	10-item	1. Body composition 2. General health	1. Anthropometrics: self-reported BMI 2. Self-reported description of general health	1. ↑ BMI 2. ↓ General health
El Zein et al., 2020 [49]	683	8 United States universities (University of Florida, University of Maine, University of Tennessee, Auburn University, South Dakota State University, Kansas State University, Syracuse University,	10-item	1. Obesity 2. Dietary intake	1. Anthropometrics: BMI, waist, hip, and neck circumference collected by a trained researcher 2. NCI 26-item DSQ	1. ↑ BMI; ↑ waist and hip circumference in females only 2. ↓ F/V; ↑ added sugars; ↑ SSB

(*continued on next page*)

Table 1 (*continued*)

Citation	Sample size (n)	Participant characteristics	USDA FSSM version	Health outcomes	Assessment tool	Outcomes associated with FI
		and West Virginia University Female: 69.6% Non-White: 52.2% FI: 25.5%				
Olfert et al., 2020 [33]	22,153	Multiple United States universities Female: 74.0% Non-White: 17.7% FI: 44.1%	10-item	1. Body composition 2. General health	1. Anthropometrics: self-reported BMI 2. Self-reported description of general health	1. ↑ BMI 2. ↓ General health
Soldavini et al., 2020 [27]	4829	University of North Carolina at Chapel Hill Female: 72.0% Non-White: 30.5% FI: 22.2%	10-item	1. General health	1. Self-reported description of general health	1. ↓ General health
Umeda et al., 2020 [79]	176	University of Texas at San Antonio Female: 45.5% Non-White: 84.1% FI: 24.4	10-item	1. Body composition	1. Anthropometrics: self-reported BMI	1. No Δ in BMI
Boone et al., 2021 [39]	226	Appalachian State University Female: 65% Non-White: 23.9% FI: 46%	10-item	1. General health 2. Daily servings of F/V 3. Body composition	1. Self-reported description of general health 2. MyPlate food recall 3. Anthropometrics: self-reported BMI	3. ↓ General health 4. ↓ F/V; ↑ added sugars and sweets 5. ↑ BMI
Davitt et al., 2021 [29]	1434	Iowa State University Female: 61.2% Non-White: 18.1% FI: 17.4%	6-item	1. Dietary intake 2. Body composition 3. General health	1. Validated food frequency screener for fruit, vegetables, and fiber 2. Anthropometrics: self-reported BMI 2. Self-reported description of general health	1. No Δ in total F/V intake, ↓ whole fruit and "other vegetables" 2. ↑ BMI 3. ↓ General health
Frank et al., 2021 [78]	232	Kent State University Female: 82.3% Non-White: 16.8% FI: 37.5%	6-item	1. Body composition	1. Anthropometrics: self-reported BMI	1. No Δ in BMI
Hiller et al., 2021 [32]	675	Iowa State University Female: 66.4% Non-White: 20.9% FI: 32.0%	10-item	1. General health	1. Self-reported description of general health	1. ↓ General health
Huelskamp et al., 2021 [75]	547	University of North Carolina Wilmington Female: not reported Non-White: not reported FI: 62.6%	10-item	1. Body composition	1. Anthropometrics: self-reported BMI	1. ↑ BMI

(*continued on next page*)

Table 1 (*continued*)

Citation	Sample size (n)	Participant characteristics	USDA FSSM version	Health outcomes	Assessment tool	Outcomes associated with FI
Leung et al., 2021 [31]	793	University of Michigan Female: 50% Non-White: 43% FI: 33.6%	10-item	1. General health	1. Self-reported description of general health	1. ↓ General health
Mei et al., 2021 [51]	1033	University of Michigan Female: 48% Non-White: 45% FI: 14%	6-item	1. Dietary intake 2. Beverage intake	1. NCI 26-item DSQ 2. BEV-Q	1. ↓ F/V intake, ↓ fiber, ↑ added sugars 2. ↑ SSB
Ryan et al., 2021 [34]	257	New York University Female: 81% Non-White: 72% FI: 41%	6-item	1. General health 2. Dietary intake 3. Beverage intake	1. Self-reported description of general health 2. All-day F/V screener 3. BEV-Q	1. ↓ General health 2. No Δ in F/V intake 3. ↑ SSB (>100 kcals/d)
Sackey et al., 2021 [58]	302	Rutgers University Female: 77.5% Non-White: 46.3% FI: 28.5%	6-item	1. Diet quality	1. Self-reported rating of diet quality	1. ↓ Diet quality
Silva et al., 2021 [56]	502	Texas Women's University Female: 87.5% Non-White: 59.6% FI: 34.5%	6-item	1. Dietary intake 2. Body composition	1. ASA24, HEI 2. Anthropometrics: self-reported BMI	1. ↓ HEI 2. No results reported
Willis, 2021 [36]	300	University of Missouri at Kansas City Female: 73.3% Non-White: 22.3% FI: 28.7%	6-item	1. Body composition 2. General health 3. F/V intake	1. Anthropometrics: self-reported BMI 2. Self-reported description of general health 3. Self-reported weekly servings	1. No Δ BMI 2. ↓ General health 3. Δ Between groups not reported
Ahmed et al., 2022 [30]	1989	2 community colleges and 1 4-y university in the City University of New York Female: 71.6% Non-White: 84% FI: 31.8%	10-item	1. General health	1. Self-reported description of general health	1. ↓ General health
Aldaz et al., 2022 [57]	250	University of California, Merced Female: 69.6% Latinx: 54.4% FI: 55.2%	6-item	1. Dietary intake 2. Diet quality 3. Body composition 4. Vascular function 5. Blood glucose	1. ASA24 2. HEI 3. Anthropometrics: BMI collected by a trained researcher; BIA 4. BP; EndoPat 5. Glucometer	1. No Δ dietary intake 2. No Δ HEI scores 3. No Δ blood glucose 4. No Δ bp; No Δ endothelial function 5. No Δ blood glucose
Levy et al., 2022 [53]	749	Texas State University Female: 76.0% Non-White: 20.3% FI: not reported	6-item	1. F/V intake	1. F/V intention ccale and FLASHE	1. ↓ F/V

(*continued on next page*)

Table 1 (*continued*)

Citation	Sample size (n)	Participant characteristics	USDA FSSM version	Health outcomes	Assessment tool	Outcomes associated with FI
Soldavini et al., 2022 [35]	263	University of North Carolina at Chapel Hill Female: 57% Non-White: Not reported – all international students FI: 25%	10-item	1. Body composition 2. General health	1. Anthropometrics: self-reported BMI 2. Self-reported description of general health	1. No Δ BMI 2. ↓ General health
Marshall et al., 2023 [52]	189	Howard University and University of Iowa Female: 68.8% Non-White: 55.7% FI: 46%	10-item	1. Diet quality	1. sHEI	1. ↓ F/V; ↑ added sugars; ↑ SSB

ASA24, automated self-administered 24-h dietary assessment tool; BEV-Q, beverage intake questionnaire-15; BMI, body mass index; BP, blood pressure; DSQ, dietary screener questionnaire; F/V, fruit and vegetables; FI, food insecurity; FLASHE, family life, activity, sun, health, and eating survey; FSS, food security status; FSSM, food security survey module; HEI, healthy eating index; NCI, national cancer institute; sHEI, short healthy eating index; SSB, sugar sweetened beverage; UC, University of California; USDA, United States department of agriculture; BIA, bioelectrical impedance analysis; EndoPat, endothelial and peripheral arterial tone.

Δ = change; ↑ = increase; ↓ = decrease.

kg/m^2) is habitually underestimated by both biological sexes, although the underestimation of weight occurs to a greater magnitude in females than males; therefore, the impact of FI on weight status may be higher than reported [76,77]. As college students are generally classified as young, healthy adults, independent of FSS, some research findings did not detect significant differences in BMI between individuals who were FS compared to those who were FI [23,35,36,48,54,57,78–80]. It has also been observed that college students tend not to adhere to dietary or physical activity guidelines, leading to an increased risk of universal weight gain, regardless of socioeconomic status [81,82]. In recent research, only 1 study included the use of bioelectrical impedance to assess body composition [57], with no known literature on the influence of FI on body composition in college students using dual-energy x-ray absorptiometry, bone, and total water density or other more accurate and objective measures of adiposity.

The overconsumption of total energy and nutrient intake can be assessed through traditional dietary intake measurements, although the recorded stigmatization of the experience of FI for college students may result in additional reporting biases when asked to self-report eating behaviors [83]. Objective measures of overnutrition are generally more financially burdensome and require substantially more resources, such as time and geographic proximity, to collect participant body composition data. The use of blood glucose monitors and EndoPat, a noninvasive measure of endothelial dysfunction, to determine differences by FSS was implemented in 1 study; however, no significant differences in hemoglobin A1C or endothelial function outcomes were observed between FI and FS participants, respectively [57]. This highlights the challenges associated with using clinical outcomes that may not be sensitive enough to detect changes in health-related biomarkers because college students are a relatively healthy young adult population despite the high prevalence of FI. To better capture the experience of FI on overnutrition in college students, user-prompted technologies, such as phone camera adiposity measurements [84] and wearable dietary monitors for assessing nutrients of concerns for both under- and overconsumption [85], may provide additional objective measures of dietary intake and health status in this population. These technologies are historically underutilized in low-income populations and have yet to be implemented in college students experiencing FI [86].

FI and psychosocial health outcomes

With the emergence of the field of nutritional psychology and nutritional psychiatry, the relationship between diet and mental health and the mechanisms driving the psychological response is advancing [87,88] (Table 2).

FI and psychological distress

Psychological distress includes a multitude of mental health outcomes, such as depression and anxiety, and the associated feelings that can accompany these concerns [89]. In the experience of FI in college students, psychological distress was measured using the Diener Flourishing Scale, which measures various aspects of human functioning, such as positive relationships, life purpose, and feelings of competence [90]. Studies

Table 2
Included studies published within the years 2013–2023 examining the relationship between food insecurity, mental health, and cognitive outcomes in college students in the United States

Citation	Sample size (n)	Participant characteristics	USDA FFSM version	Health outcomes	Assessment tool	Outcomes associated with FI
Bruening et al., 2018 [48]	1138	Multiple universities in Arizona Female: 65% Non-White: 49% FI: 32.8%	6-item	1. Stress 2. Depression	1. Cohen's PSS 2. ACHA-NCHA	1. ↑ Stress 2. ↑ Depression
Payne-Sturges et al., 2018 [26]	237	University of Maryland Female: 81% Non-White: 51% FI: 15%	18-item	1. Depression	1. PHQ-9	1. ↑ Depressive symptoms
Wattick et al., 2018 [101]	1956	West Virginia University Female: 67.5% Non-White: not reported FI: 36.7%	Used the USDA tool – version not specified	1. Depression 2. Anxiety	1. and 2. CDC healthy days core module	1. ↑ Depression 2. ↑ Anxiety
Diamond et al., 2019 [106]	1229	University of Minnesota – Twin Cities Female: 64.7% Non-White: 23.9% FI: 32% long term; 36% short-term	6-item	1. Depression 2. Stress 3. Social isolation 4. Resiliency	1. PHQ-9 2. Cohen's PSS 3. 3-item loneliness scale 4. 6-item brief resiliency scale	1. ↑ Depression 2. ↑ Stress 3. ↑ Social isolation 4. ↓ Perceived resiliency
El Zein et al., 2019 [80]	855	8 United States universities (University of Florida, University of Maine, University of Tennessee, Auburn University, South Dakota State University, Kansas State University, Syracuse University, and West Virginia University Female: 68.8% Non-White: 37.6% FI: 19%	10-item	1. Stress 2. Sleep 3. Disordered eating behaviors	1. Cohen's PSS 2. PSQI 3. Eating attitudes Test-26	1. ↑ Stress 2. ↓ Sleep 3. ↑ Risk of disordered eating behaviors
Raskind et al., 2019 [104]	2377	7 Georgia colleges and universities Female: 64% Non-White: 38% FI: 29%	6-item	1. Depression 2. Anxiety 3. Hope	1. PHQ-9 2. ASI-3 3. 6-item adult state hope scale	1. ↑ Depression 2. ↑ Anxiety 3. ↓ Hope

(continued on next page)

Table 2 (*continued*)

Citation	Sample size (n)	Participant characteristics	USDA FFSM version	Health outcomes	Assessment tool	Outcomes associated with FI
Becerra et al., 2020 [96]	302	California State University, San Bernardino Female: 63% Latinx: 67.9% FI: 37.5%	6-item	1. Psychological distress	1. Kessler-6 scale	1. ↑ Psychological distress
Becerra et al., 2020 [133]	282	California State University, San Bernardino Female: 86.6% Latinx: 64.8% FI: not reported	6-item	1. Sleep	1. Berlin sleep questionnaire	1. ↑ Tiredness, sleepiness, fatigue; ↓ sleep duration
Haskett et al., 2020 [94]	1330	North Carolina State University Female: 55.7% Non-White: 25% FI: 15.5%	10-item	1. Well-being	1. WHO-5	1. ↓ Psychological well-being
Martinez et al., 2020 [166]	8765	UC campuses (UC Berkeley, UC Davis, UC San Francisco, UC Riverside, UC Merced, UC San Diego, UC Santa Cruz, UC Santa Barbara, UC Los Angeles, UC Irvine) Female: 67% Non-White: 66% FI: 39.5%	6-item	1. Mental health	1. ACHA-NCHA	1. ↑ Poor mental health
Reeder et al., 2020 [105]	131	Mississippi State University Female: 72.5% Non-White: 29% FI: 38.2%	6-item	1. Depression 2. Substance abuse	1. PHQ-9 2. AUDIT	1. ↑ Depression 2. No Δ in AUDIT scores
Richard et al., 2020 [132]	153	University of Tennessee at Martin Female: 76.1% Non-White: 16.6% FI: 34%	6-item	1. Sleep 2. Stress 3. Dietary cognitive restraint	1. PSQI 2. PSS 3. TFEQ-R18V2	1. ↓ Sleep 2. ↑ Stress 3. ↑ Uncontrolled eating
Umeda et al., 2020 [79]	176	University of Texas at San Antonio Female: 45.5% Non-White: 84.1% FI: 24.4%	10-item	1. Depression 2. Pain	1. BDI-II 2. BDS	1. No Δ in depressive symptoms 2. ↑ Pain interference
Barry et al., 2021 [150]	851	University of Michigan Female: 50.4% Non-White: 35% FI: 35.1%	10-item	1. Disordered eating behaviors	1. SCOFF-5	1. ↑ Positive SCOFF-5 screens

(*continued on next page*)

Table 2 (*continued*)

Citation	Sample size (n)	Participant characteristics	USDA FFSM version	Health outcomes	Assessment tool	Outcomes associated with FI
Cockerham et al., 2021 [110]	55	Sam Houston State University Female: 87.3% Non-White: not reported FI: 60%	6-item	1. Social support	1. MSPSS	1. ↓ Social support
Coffino et al., 2021 [108]	263	University at Albany Female: 69% Non-White: 31.1% FI: 40.3%	6-item	1. Depression 2. Anxiety 3. Stress	1.– 3. DASS-21	1. ↑ Depression 2. ↑ Anxiety 3. ↑ Stress
DeBate et al., 2021 [92]	1743	University of South Florida Female: 69.2% Non-White: 47.1% FI: 46.8%	6-item	1. Psychological well-being 2. Psychological distress 3. Loneliness 4. Resilience 5. Suicidal behaviors	1. Diener flourishing scale 2. Kessler-6 scale 3. UCLA 3-item loneliness scale 4. CD-RISC 5. SBQ-R	1. ↓ Psychological well-being 2. ↑ Psychological distress 3. ↑ Loneliness 4. ↓ Resiliency 5. ↑ Suicidal behaviors
Frank et al., 2021 [78]	232	Kent State University Female: 82.3% Non-White: 16.8% FI: 37.5%	6-item	1. Disordered eating behaviors	1. EES	1. ↑ Emotional eating
Hagedorn et al., 2021 [99]	17,686	Multiple ($n = 22$) United States universities Female: 74.8% Non-White: 16.5% FI: 43.4%	10-item	1. Sleep quality 2. Mental well-being	1. PSQI 2. CDC healthy days core module	1. ↓ Sleep 2. ↑ Days with poor mental health
Leung et al., 2021 [31]	793	University of Michigan Female: 50% Non-White: 43% FI: 33.6%	10-item	1. Depression	1. PHQ-4	1. ↑ Depression
Matias et al., 2021 [120]	171	University of California, Berkeley Female: 62.6% Non-White: 88.9% FI: 52.1%	6-item	1. Stress	1. PSS	1. No Δ in stress levels
Royer et al., 2021 [151]	533	Arizona State University Female: 77.7% Non-White: 52.9% FI: 39.4%	10-item	1. Disordered Eating Behaviors	1. EDE-Q	1. ↑ Global DEBS, eating concern, shape concern, weight concern, no Δ in restraint
Ryan et al., 2021 [34]	257	New York University Female: 81% Non-White: 72% FI: 41%	6-item	1. Sleep	1. PSQI	1. No Δ in sleep patterns

(*continued on next page*)

Table 2 (*continued*)

Citation	Sample size (n)	Participant characteristics	USDA FFSM version	Health outcomes	Assessment tool	Outcomes associated with FI
Willis, 2021 [36]	300	University of Missouri at Kansas City Female: 73.3% Non-White: 22.3% FI: 28.7%	6-item	1. Depression	1. CES-D	1. ↑ Depressive symptoms
Ahmed et al., 2022 [30]	1989	2 community colleges and 1 4-y university in the City University of New York Female: 71.6% Non-White: 84% FI: 31.8%	10-item	1. Psychological well-being	1. Diener flourishing scale	1. ↓ Psychological well-being
Aldaz et al., 2022 [57]	250	University of California, Merced Female: 69.6% Latinx: 54.4% FI: 55.2%	6-item	1. Cognitive tests for attention and memory	1. Immediate memory recall; attention test	1. ↓ Cognitive performance
Coakley et al, 2022 [100]	833	University of New Mexico Female: 65.8% Non-White: 62.8% FI: 25.6%	10-item	1. Depression 2. Anxiety 3. Mental well-being	1. PHQ-2 2. GAD-2 3. CDC healthy days core module	1. ↑ Depression 2. ↑ Anxiety 3. ↑ Risk of fair/poor mental health
ElTohamy et al., 2022 [98]	59,250	Multiple United States universities (ACHA-NCHA $n = 75$) Female: 68.1% Non-White: 48.5% FI: 35.9%	Used the USDA tool – version not specified	1. Psychological distress	1. Kessler-6 scale	1. ↑ Psychological distress
Guerithault et al., 2022 [121]	40	Arizona State University Female: 50% Non-White: 57.5% FI: 50%	10-item	1. Brain Activity 2. Executive function 3. Childhood trauma	1. Structural and functional MRI 2. BRIEF-2 3. ACEs	1. Δ Functional connectivity between key cognitive networks 2. ↓ Executive function 3. ↑ ACEs
Guzman et al., 2022 [95]	441	San Diego State University Female: 76.7% Non-White: 63.5% FI: 33.8%	6-item	1. Psychological distress 2. Loneliness	1. Kessler-6 scale 2. UCLA 3-item loneliness scale	1. ↑ Psychological distress 2. ↑ Loneliness
Harris et al., 2022 [111]	2062	University of Washington Female: 72.0% Non-White: 47.5% FI: 17.9%	6-item	1. Eating competence 2. Discrimination	1. ecSI 2.0 2. EDS	1. ↓ Eating competence 2. ↑ Discrimination

(*continued on next page*)

Table 2 (*continued*)

Citation	Sample size (n)	Participant characteristics	USDA FFSM version	Health outcomes	Assessment tool	Outcomes associated with FI
Mahoney et al., 2022 [97]	308	California State University, San Bernardino Female: 63.0% Latinx: 82.9% FI: 37.4%	6-item	1. Psychological distress 2. Discrimination	1. Kessler-6 scale 2. EDS	1. ↑ Psychological distress 2. ↑ Discrimination
Marmolejo et al., 2022 [91]	48,103	Multiple United States universities (ACHA-NCHA $n = 75$) Female: 68.5% Non-White: 37.7% FI: 40.7%	6-item	1. Psychological well-being 2. Loneliness 3. Psychological distress	1. Diener flourishing scale 2. UCLA 3-item loneliness scale 3. Kessler-6 scale	2. ↑ Psychological distress 3. ↑ Loneliness 4. ↓ Psychological well-being
Neal et al., 2022 [103]	589	Southern Connecticut State University Female: 69.4% Non-White: 41.9% FI: 38.5%	6-item	1. Depression	1. PHQ-9	1. ↑ Depression
Kim et al., 2023 [107]	375	Virginia Commonwealth University Female: 82.9% Non-White: 46.9% FI: 35.0%	6-item	1. Mental health symptoms	1. PHQ-4	1. ↑ Mental health symptoms
Umeda et al., 2023 [109]	360	University of Texas at San Antonio Female: 50.6% Non-White: 83.3% FI: 19.4%	10-item	1. Depression 2. Anxiety 3. Pain	1. BDI-II 2. Trait anxiety inventory 3. BDS	1. ↑ Depressive symptoms 2. ↑ Anxiety 3. ↑ Pain interference score

ACE, adverse childhood experiences; ACHA-NCHA, American college health association national college health assessment; ASI-3, anxiety sensitivity index; AUDIT, alcohol use disorders identification test; BDI-II, beck depression inventory-II; BDS, bodily pain scale; BRIEF-2, behavior rating inventory of executive function-2; CDC, centers for disease control and prevention; CD-RISC, Connor-Davison resiliency scale; CES-D, Center for Epidemiologic Studies Depression Scale; Cohen's PSS, Cohen's perceived stress scale; DASS-21, depression anxiety and stress scales – 21-item short form; ecSI 2.0, eating competency scale; EDE-Q, Eating Disorder Examination Questionnaire; EDS, emotional eating survey; EES, everyday discrimination scale; GAD-2, generalized anxiety disorder screener; GAD-7, general anxiety disorder – 7; MRI, magnetic resonance imaging; MSPSS, multidimensional scale of perceived social support; PHQ-2, patient health questionnaire-2; PHQ-9, patient health questionnaire – 9; PSQI, Pittsburg sleep quality index; SBQ-R, suicidal behaviors questionnaire; SCOFF-5, sick, control, one stone, fat, food; TFEQ-R18V2, three factor eating questionnaire revised; UC, University of California; UCLA, University of California, Los Angeles; USDA, United States department of agriculture; WHO-5, world health organization 5 factor well-being index; DEBS, disordered eating behavior survey.

Δ = change; ↑ = increase; ↓ = decrease.

using the Diener Flourishing Scale found that college students with FI had significantly higher psychological distress than their FS counterparts [30,91,92]. Psychological well-being was also assessed in select studies through the Kessler-6 Scale [93] or the WHO Five Factor Well-being Index [94], in which individuals experiencing FI had lower overall psychological well-being than FS peers [91,92,94–98]. A more general mental health assessment through the Centers for Disease Control and Prevention Healthy Days Core Module found that college students with FI were at an increased risk for poor mental health status [99–101].

The relationship between depression and FI in college students was primarily assessed using a version of the patient health questionnaire, which estimates risk of depression in accordance with the criteria presented in the Diagnostic and Statistical Manual of Mental Disorders [102]. The experience of FI resulted in higher rates of depressive symptoms in every study that used the patient health questionnaire assessment [26,31,100,103–107]. Other measures of depression and depressive symptoms have also been implemented in the research setting, such as the Depression Anxiety and Stress Scales – 21-item short form (DASS-21) [108], the Center for Epidemiologic Studies Depression Scale [36], the Beck Depression Inventory-II [79, 109], with only 1 study implementing the Beck depression inventory-II not to report significant differences in depression symptoms between FI and FS college students [79].

Similarly, with depression, the relationship between anxiety and FI was predominately measured using an adapted version of the Generalized Anxiety Disorder questionnaire [100], the DASS-21 [108], the Trait Anxiety Index [109], and the Anxiety Sensitivity Index [104]. It was observed that anxiety symptoms increased with the experience of FI in the college student population, independent of the measurement tool used [100,104,108, 109]. Additional psychological outcomes associated with depression and anxiety include feelings of loneliness [91,92,95,106,110], hopelessness [104], resiliency [92,106], discrimination [97,111], pain [79,109], and suicidal behaviors [92], all of which were measured by validated subjective assessments and were negatively impacted by the experience of FI (Table 2).

Reliance on subjective and self-reported mental health measures is a common practice when assessing psychological outcomes. However, developing active and passive data collection procedures may provide more consistent mental health monitoring that reduces recall bias [112,113]. Gamified applications are emerging as a strategy for identifying college individuals experiencing mental health concerns and providing immediate services for support [114]. With the increased support for mental health resources on college campuses, electronic health records may be used to determine risk factors for medical diagnoses health care practitioners to quantify mental health pervasiveness better [115]. Research on developing clinical and subclinical biomarkers for personalized mental health risk factors is ongoing [116].

FI and stress

Feelings of stress are not isolated to the experience of FI in the college student population. Stress in the college environment is ubiquitous, stemming from academic, financial, social, familial, or other life stressors [117]. The experience of stress may serve as a bidirectional mediator to increasing the etiologies of overnutrition with FI, as stress status may result in the consumption of highly palatable foods, which, over time, can cause excessive weight gain [118].

Stress levels are commonly measured as a psychological health outcome of FI using the validated Cohen's Perceived Stress Scale [48,80,106,119,120] and the DASS-21 [108]. Individuals experiencing FI consistently had higher self-reported stress levels than their FS counterparts. The implementation of the Adverse Childhood Experiences Survey is used as a measure of stress and FI during childhood [121], although this assessment only provides a glimpse into the severity and duration of stress across the lifespan [122]. Expectedly, risk of experiencing FI during college years is significantly associated with adverse childhood experiences exposures [123].

Few objective measures of stress are implemented in the clinical research setting. Because of the variability in diurnal fluctuations in plasma and salivary cortisol, using less volatile biomarkers may better discern the relationship between FI and stress [124]. The development of more stable measures of cortisol to be quantified through wearable heat conductance patches [125], hair cortisol concentration [126,127], or telomere length [128] may provide a more in-depth understanding of how stress levels are impacted by the experience of FI in the college student population.

FI and sleep

Whether attributed to elevated stress and cortisol levels or the underconsumption of nutrients involved in sleep regulation, such as protein (amino acid tryptophan), folic acid, zinc, or vitamin B-12, the experience of FI can influence the quality and/or quantity of sleep [129,130]. Independent of FSS, college students often experience reduced sleep duration and higher sleep disturbances because of increased academic and social responsibilities [131]. Under the experience of FI, these negative sleep outcomes are further exacerbated in college students.

Research on the association between FI and sleep outcomes in college students has been measured using the Pittsburg Sleep Quality Index [34,80,99,119] and the Berlin Sleep Questionnaire [132]. The Pittsburg Sleep Quality Index is a clinically validated 18-item assessment that estimates sleep quality and disturbances over a 1-mo period [133], whereas the Berlin Sleep Questionnaire measures is designed to measure obstructive sleep-related disorders, such as sleep apnea [134]. It was observed that the experience of FI resulted in a reduction in a multitude of sleep-related behaviors, including sleep duration, frequency of interruptions, sleep latency, and feelings of fatigue and tiredness [80,99,119,132], with the exception of 1 study that did not report significant differences in sleep by FSS [34].

There are objective measures of sleep that have been measured in relationship to FI, although to date, these assessments have not been implemented in the college student population [135]. Actigraphy continuously measures an individual's movement and heart rate to derive circadian rhythmic parameters to estimate sleep/wake cycles [136]. Such actigraphy devices can be found in commercially available activity-based trackers [137,138] and sleep rings [138–140], making them easily accessible for research purposes. Assessing the accuracy and validity of sleep tracking technology is ongoing, as there are many internal and environmental factors that can affect sleep duration and quality, such as biological sex, body weight, and pulse oxygen rates with sleep apnea, among others [141]. Although these discrepancies between sleep monitoring devices have been previously identified, objective measures of sleep may provide more reliable estimates of sleep-related outcomes than self-report [142,143].

FI and substance abuse

In the experience of FI, it has been observed that individuals struggling with addiction may prioritize drug or alcohol intake over food [144]. Validated for use in college student populations, the Alcohol Use Disorders Identification Test measures risk for a range of alcohol-related behaviors [145]. Only 1 study within the last 5 y assessed alcohol abuse risk using the Alcohol Use Disorders Identification Test tool, and no significant differences were observed by FSS [105]. Additional studies prompt students to report alcohol and drug habits through questions such as “During the past 30 days, how many days did you drink alcohol or use drugs?” [103]. Standardized assessments specifically for use in the college student setting include 9 tools to determine alcohol-related problems [146]. Novel assessments, including the digital communication strategies for identifying, diagnosing, and treating drug- and alcohol-related behaviors, are ongoing in the college student population [147]; further, implementing the USDA FSSM would provide additional insight into the role of FI on drug and alcohol intake.

FI and disordered eating behaviors

Because of disrupted eating patterns under the experience of FI, risk of disordered eating behaviors may subsequently increase [148]. In the college student population, disordered eating behaviors include binge eating, body dysmorphia, and concerns about weight [149]. Using the Eating Attitudes Test [80], 5-item Sick, Control, One Stone, Fat, Food Questionnaire-5 [149], the Eating Disorder Examination Questionnaire [150], the Eating Competency Scale (ecSI 2.0) [111], and the emotional eating survey [78], positive associations between FI and risk of disordered eating behaviors were observed in all assessments. The continued screening and detection of disordered eating behaviors in the college student population is warranted to explore the efficacy of pharmacological and community-based interventions aimed at reducing the compounded risk of FI with disordered eating behaviors [151,152].

FI and cognitive outcomes

Cognitive function refers to the ability to acquire, store, and process information through 6 domains: memory and learning, language, executive function, complex attention, social cognition, and perceptual and motor functions [153]. The experience of FI may affect 1 or more domains of cognitive function because of the impact of nutritional deficiencies, elevated stress levels, lack of sleep, or a combination of the various health outcomes previously discussed [154]. Inverse relationships between neural connectivity, cognitive function, and FI have been observed across the lifespan [155,156], with a considerable focus on the older adult population [154,157–159]; however, there is limited research addressing this relationship in college students [121].

Cognitive function can be assessed both objectively and subjectively. Objective measures used to determine the relationship between FI and cognitive outcomes include MRI to determine the anatomical structure of the brain and fMRI to assess neural network activity [121,160]. MRI imaging can be burdensome to participants, as the process for obtaining images is both time-intensive and physically uncomfortable, as it requires the subject to remain still for an extended period of time. Additionally, implementing brain imaging technology requires advanced facilities and technicians, which is costly.

Cognitive function may also be determined using objective assessment tools, such as those found within an automated cognitive battery assessment [161]. In the college student population, both memory-based and attention-based cognitive processing skills were impacted by the experience of FI [57]. Additional research is needed on the different domains of executive function to determine the impact of FI on decision-making behavior in this population, where cognitive development and maturation are still in progress. Subjective measures of cognition used in the college student population include the behavior rating inventory of executive function-2 (BRIEF-2) assessment, a self-reported questionnaire that has participants rate the frequency of difficulty with tasks, the inability to problem solve, and other intrapersonal cognitive qualities [121]. In college students, individuals experiencing FI had higher BRIEF-2 scores, which reflects poorer cognitive function. Although the BRIEF-2 assessment is subjective and relies on participant perception, BRIEF-2 scores were correlated with the objective outcome of neural connectivity from fMRI output in various brain regions [121].

Cognitive restraint with regard to food-making decisions has also been assessed as it relates to the FI in the college student population [119]. Using the Three Factor Eating Questionnaire-18, a self-reported questionnaire that calculates a score for emotional eating, uncontrolled eating, and cognitive restraint, it was observed that only uncontrolled eating scores were significantly associated with the experience of FI [119]. Further research into the role of FI on cognitive function is warranted as many college students are still experiencing brain maturation that impacts cognitive development up through the age of 24 y [162]. Concerns regarding the high prevalence of FI impacting cognitive processes in college students may also be recognized through decreased academic performance [3,26,30,92,104,163–169] and other cognitively derived outcomes.

The use of objective measures of the domains of cognitive function is critical to understand further the driving mechanisms behind the experience of FI on neural development and cognitive function. Research findings have elucidated the potential antioxidant role of carotenoids [170], flavonoids [171], and other phytochemicals [172] on cognitive health. As the diet quality is impacted by the experience of FI, health-promoting phytonutrients may not be consumed as frequently, and neuroinflammatory foods, such as saturated fats and added sugars, may be consumed more regularly, ultimately resulting in increased intestinal permeability, causing gut-brain dysbiosis to compromise the blood-brain barrier [173]. Future research to explore the potential for cognitive flexibility and reversibility of cognitive decline with the experience of acute and/or chronic FI on brain development is needed.

Limitations

It is apparent from reviewing the recent literature that the field of FI research in college students consists predominately of subjective assessments for health outcomes. The studies included in this review are predominately cross-sectional and, therefore, have the opportunity for larger sample populations, ranging from 40 to 59,250 participants. Because of the observational nature of this work, elucidating cause-and-effect relationships is not plausible. For this reason, only studies that used previously validated assessment tools were included, resulting in the omission of qualitative research studies that relied on participant verbal responses. The focus of this review on the college student population was selected because of the disproportionate rates of FI compared to the United States household prevalence; however, research in other populations, such as children, adolescents, or older adults, may yield additional assessment tools not yet implemented in the college setting.

In conclusion, this narrative review explores the recent literature on assessment methods used to determine physiological, psychosocial, and cognitive outcomes that are impacted by the experience of FI in college students. Findings from this review highlight the myriad of negative health outcomes associated with the experience of FI in college students. The dearth of clinical and subclinical biomarkers makes it challenging to assess other determinants of FI, such as the severity of acute and chronic FI on physical and mental well-being [174]. It is essential to identify the underlying mechanisms and pathways between FI and health outcomes to develop targeted interventions aimed at improving FSS in the college student population.

Future directions

The disproportionate rates of FI in the college student population, along with the implicated health outcomes, are imperative to address. College students as a study population present a unique set of juxtaposed challenges in that the demographic is relatively young, healthy, and well-educated, yet experience excessive stress levels, poor sleep, adverse mental health outcomes, and high rates of FI. Although the health outcomes associated with FI are not siloed to the college student population, the high prevalence of FI during this crucial period of the life stage may leave devastating long-term health consequences into older adulthood. This review serves as a call for action to implement objective biomarkers to assess the outcomes of FI in all populations, emphasizing the distinct yet concerning characteristics of college students.

Future directions are 2-fold: incorporating objective biomarkers to address the clinical research gaps and the development of effective interventions at the public health and policy level to improve FSS. The incorporation of food, nutrition, and financial literacy programs into primary and secondary school curricula to develop awareness around food and budgeting, as well as in the collegiate setting, when dietary behaviors are more autonomous, may serve as effective interventions to reduce health disparities from the experience of FI [175, 176]. Geographic Information Systems may also be a novel approach to geocoding dietary behaviors by socioeconomic status to better identify at-risk college student populations [177]. As FI is an interdisciplinary and multifaceted public health concern, effective interventions to alleviate the health impacts require collaboration in areas of nutrition, medicine, agriculture, sustainability, and technology, among many others.

Author contributions

The authors' responsibilities were as follows– MDR, FMS, and RES: conceptualized the review; MDR and RES: conducted the literature search; MDR and RES: drafted the manuscript, tables, and figures; all authors provided constructive edits, and all authors: reviewed and approved the final manuscript.

Conflict of interest

The authors report no conflicts of interest.

Funding

The authors reported no funding received for this study

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.advnut.2023.10.004.

References

[1] C.J. Nikolaus, R. An, B. Ellison, S.,M. Nickols-Richardson, Food insecurity among college students in the United States: A scoping review, Adv. Nutr. 11 (2) (2020) 327–348, https://doi.org/10.1093/advances/nmz111.

[2] United States Department of Agriculture Economic Research Service, Key statistics & graphics – food security status of U.S. Households, 2021. Accessed March 25, 2023. Available from: https://www.ers.usda.gov/topics/food-nutrition-assistance/food-security-in-the-u-s/key-statistics-graphics/#foodsecure.

[3] V. Zigmont, A. Linsmeier, P. Gallup, Understanding the why of college student food insecurity, J. Hunger Environ. Nutr. 16 (5) (2021) 595–610, https://doi.org/10.1080/19320248.2019.1701600.

[4] S.N. Zenk, L.A. Tabak, E.J. Pérez-Stable, Research opportunities to address nutrition insecurity and disparities, JAMA 327 (20) (2022) 1953, https://doi.org/10.1001/jama.2022.7159. –4.

[5] B. Butrum, D.M. Mitchum, F.A. Hunter, L. Littlejohn, M. Young, D. Rutberg, et al., Notice of special interest (NOSI): stimulating research to understand and address hunger, food and nutrition insecurity. Accessed March 25, 2023. Available from: https://grants.nih.gov/grants/guide/notice-files/not-od-22-135.html.

[6] United States Department of Agriculture. Definitions of food security 2021. Accessed March 25, 2023. Available from: https://www.ers.usda.gov/topics/food-nutrition-assistance/food-security-in-the-us/definitions-of-food-security/.

[7] United States Department of Agriculture Economic Research Service. Food security in the U.S.: measurement. Accessed March 25, 2023. Available from: https://www.ers.usda.gov/topics/food-nutrition-assistance/food-security-in-the-u-s/measurement/#measurement.

[8] E.R. Hager, A.M. Quigg, M.M. Black, S.M. Coleman, T. Heeren, R. Rose-Jacobs, et al., Development and validity of a 2-item screen to identify families at risk for food insecurity, Pediatrics 126 (1) (2010) e26, https://doi.org/10.1542/peds.2009-3146, 32.

[9] D.P. Keenan, C. Olson, J.C. Hersey, S.M. Parmer, Measures of food insecurity/security, Suppl 1, J. Nutr. Educ. 33 (1) (2001) S49, https://doi.org/10.1016/s1499-4046(06)60069-9. –58.

[10] A.D. Jones, F.M. Ngure, G. Pelto, S.L. Young, What are we assessing when we measure food security? A compendium and review of current metrics, Adv. Nutr. 4 (5) (2013) 481–505, https://doi.org/10.3945/an.113.004119.

[11] J. Ingram, Nutrition security is more than food security, Nat. Food. 1 (1) (2020) 2, https://doi.org/10.1038/s43016-019-0002-4.

[12] G.G.C. Kuhnle, Nutritional biomarkers for objective dietary assessment, J. Sci. Food Agric. 92 (6) (2012) 1145–1149, https://doi.org/10.1002/jsfa.5631.

[13] A. Althubaiti, Information bias in health research: definition, pitfalls, and adjustment methods, J. Multidiscip. Healthc. 9 (2016) 211–217, https://doi.org/10.2147/JMDH.S104807.

[14] A.J. Murrell, R. Jones, S. Rose, A. Firestine, J. Bute, Food security as ethics and social responsibility: an application of the food abundance

index in an urban setting, Int. J. Environ. Res. Public Health. 19 (16) (2022) 10042, https://doi.org/10.3390/ijerph191610042.
[15] United Nations human rights office of the high Commisioner. About the universal declaration of human rights translation project. Accessed March 25, 2023. Available from: https://www.ohchr.org/en/human-rights/universal-declaration/universal-declaration-human-rights/about-universal-declaration-human-rights-translation-project.
[16] R. Loopstra, Interventions to address household food insecurity in high-income countries, Proc. Nutr. Soc. 77 (3) (2018) 270–281, https://doi.org/10.1017/S002966511800006X.
[17] C. Gundersen, J.P. Ziliak, Food insecurity and health outcomes, Health Aff. (Millwood). 34 (11) (2015) 1830–1839, https://doi.org/10.1377/hlthaff.2015.0645.
[18] C.W. Leung, A.P. Fulay, L. Parnarouskis, E. Martinez-Steele, A.N. Gearhardt, J.A. Wolfson, Food insecurity and ultra-processed food consumption: the modifying role of participation in the Supplemental Nutrition Assistance Program (SNAP), Am. J. Clin. Nutr. 116 (1) (2022) 197–205, https://doi.org/10.1093/ajcn/nqac049.
[19] L.R. Young, M. Nestle, Portion sizes of ultra-processed foods in the United States, 2002 to 2021, Am. J. Public Health. 111 (12) (2021) 2223–2226, https://doi.org/10.2105/AJPH.2021.306513.
[20] K. Lee, J. Hyun, Y. Lee, Why do and why Don't people consume fast food?: an application of the consumption value model, Food Qual. Preference 99 (2022) 104550, https://doi.org/10.1016/j.foodqual.2022.104550.
[21] Covidence Systematic Review Software. Veritas Health Innovation, Melbourne, Austrailia. Available from: www.covidence.org. (Accessed 9 February 2023).
[22] S.M. Martinez, M.A. Grandner, A. Nazmi, E.R. Canedo, L.D. Ritchie, Pathways from food insecurity to health outcomes among California university students, Nutrients 11 (6) (2019) 1419, https://doi.org/10.3390/nu11061419.
[23] L.L. Knol, C.A. Robb, E.M. McKinley, M. Wood, Food insecurity, self-rated health, and obesity among college students, Am. J. Health Educ. 48 (4) (2017) 248–255, https://doi.org/10.1080/19325037.2017.1316689.
[24] L.H. McArthur, L. Ball, A.C. Danek, D. Holbert, A high prevalence of food insecurity among university students in Appalachia reflects a need for educational interventions and policy advocacy, J. Nutr. Educ. Behav. 50 (6) (2018) 564–572, https://doi.org/10.1016/j.jneb.2017.10.011.
[25] L.H. McArthur, K.S. Fasczewski, E. Wartinger, J. Miller, Freshmen at a university in Appalachia experience a higher rate of campus than family food insecurity, J. Community Health. 43 (5) (2018) 969–976, https://doi.org/10.1007/s10900-018-0513-1.
[26] D.C. Payne-Sturges, A. Tjaden, K.M. Caldeira, K.B. Vincent, A.M. Arria, Student hunger on campus: food insecurity among college students and implications for academic institutions, Am. J. Health Promot. 32 (2) (2018) 349–354, https://doi.org/10.1177/0890117117719620.
[27] J. Soldavini, M. Berner, The importance of precision: differences in characteristics associated with levels of food security among college students, Public Health Nutr 23 (9) (2020) 1473–1483, https://doi.org/10.1017/S1368980019004026.
[28] J. Soldavini, M. Berner, J. Da Silva, Rates of and characteristics associated with food insecurity differ among undergraduate and graduate students at a large public university in the Southeast United States, Prev. Med. Rep. 14 (2019) 100836, https://doi.org/10.1016/j.pmedr.2019.100836.
[29] E.D. Davitt, M.M. Heer, D.M. Winham, S.T. Knoblauch, M.C. Shelley, Effects of COVID-19 on university student food security, Nutrients 13 (6) (2021) 1932, https://doi.org/10.3390/nu13061932.
[30] T. Ahmed, R.T. Ilieva, J. Shane, S. Reader, C. Aleong, H.Y. Wong, et al., A developing crisis in hunger: food insecurity within 3 public colleges before and during the COVID-19 pandemic, J. Hunger Environ. Nutr. 18 (1) (2023) 1–20, https://doi.org/10.1080/19320248.2022.2026853.
[31] C.W. Leung, S. Farooqui, J.A. Wolfson, A.J. Cohen, Understanding the cumulative burden of basic needs insecurities: associations with health and academic achievement among college students, Am. J. Health Promot 35 (2) (2021) 275–278, https://doi.org/10.1177/0890117120946210.
[32] M.B. Hiller, D.M. Winham, S.T. Knoblauch, M.C. Shelley, Food security characteristics vary for undergraduate and graduate students at a midwest university, Int. J. Environ. Res. Public Health. 18 (11) (2021) 5730, https://doi.org/10.3390/ijerph18115730.
[33] M.D. Olfert, R.L. Hagedorn-Hatfield, B. Houghtaling, M.K. Esquivel, L.B. Hood, L. MacNell, et al., Struggling with the basics: food and housing insecurity among college students across twenty-two colleges and universities, J. Am. Coll. Health (2021) 1–12, https://doi.org/10.1080/07448481.2021.1978456.
[34] R.A. Ryan, B. Murphy, A.L. Deierlein, S. Lal, N. Parekh, J.D. Bihuniak, Food insecurity, associated health behaviors, and academic performance among urban university undergraduate students, J. Nutr. Educ. Behav. 54 (3) (2022) 269–275, https://doi.org/10.1016/j.jneb.2021.08.008.
[35] J. Soldavini, H. Andrew, M. Berner, Campus-based food insecurity: the case of international students at a Southeastern University, J. Stud. Aff. Res. Pract. 59 (3) (2022) 338–351, https://doi.org/10.1080/19496591.2021.1997755.
[36] D.E. Willis, Feeding inequality: food insecurity, social status and college student health, Sociol Health Illn 43 (1) (2021) 220–237, https://doi.org/10.1111/1467-9566.13212.
[37] M.M. Patton-López, D.F. López-Cevallos, D.I. Cancel-Tirado, L. Vazquez, Prevalence and correlates of food insecurity among students attending a midsize rural university in Oregon, J. Nutr. Educ. Behav. 46 (3) (2014) 209–214, https://doi.org/10.1016/j.jneb.2013.10.007.
[38] R.L. Hagedorn, M.D. Olfert, Food insecurity and behavioral characteristics for academic success in Young adults attending an Appalachian university, Nutrients 10 (3) (2018) 361, https://doi.org/10.3390/nu10030361.
[39] H.E. Boone, M.D. Gutschall, A.R. Farris, K.S. Fasczewski, D. Holbert, L.H. McArthur, Comparisons of cooking, dietary, and food safety characteristics of food secure and food insecure sophomores at a university in Appalachia, J. Appalach Health 3 (4) (2021) 89–108, https://doi.org/10.13023/jah.0304.08.
[40] I. Onur, M. Velamuri, The Gap between self-reported and objective measures of disease status in India, PLOS ONE 13 (8) (2018) e0202786, https://doi.org/10.1371/journal.pone.0202786.
[41] A.B. Krueger, A.A. Stone, Psychology and economics. Progress in measuring subjective well-being, Science 346 (6205) (2014) 42–43, https://doi.org/10.1126/science.1256392.
[42] K. Shemisa, A. Bhatt, D. Cheeran, I.J. Neeland, Novel biomarkers of subclinical cardiac dysfunction in the general population, Curr. Heart Fail Rep. 14 (4) (2017) 301–310, https://doi.org/10.1007/s11897-017-0342-z.
[43] G. Valacchi, F. Virgili, C. Cervellati, A. Pecorelli, OxInflammation: from subclinical condition to pathological biomarker, Front Physiol 9 (2018) 858, https://doi.org/10.3389/fphys.2018.00858.
[44] K. Aleksandrova, C.E. Egea Rodrigues, A. Floegel, W. Ahrens, Omics biomarkers in obesity: novel etiological insights and targets for precision prevention, Curr. Obes. Rep. 9 (3) (2020) 219–230, https://doi.org/10.1007/s13679-020-00393-y.
[45] H.K. Seligman, B.A. Laraia, M.B. Kushel, Food insecurity is associated with chronic disease among low-income NHANES participants, J. Nutr. 140 (2) (2010) 304–310, https://doi.org/10.3945/jn.109.112573.
[46] K S. Moradi, A. Mirzababaei, H. Mohammadi, S.P. Moosavian, A. Arab, B. Jannat, et al., Food insecurity and the risk of undernutrition complications among children and adolescents: A systematic review and meta-analysis, Nutrition 62 (2019) 52–60, https://doi.org/10.1016/j.nut.2018.11.029.
[47] B. Franklin, A. Jones, D. Love, S. Puckett, J. Macklin, S. White-Means, Exploring mediators of food insecurity and obesity: a review of recent literature, J. Community Health. 37 (1) (2012) 253–264, https://doi.org/10.1007/s10900-011-9420-4.
[48] M. Bruening, I. van Woerden, M. Todd, M.N. Laska, Hungry to learn: the prevalence and effects of food insecurity on health behaviors and outcomes over time among a diverse sample of university freshmen, Int. J. Behav. Nutr. Phys. Act. 15 (1) (2018) 9, https://doi.org/10.1186/s12966-018-0647-7.
[49] A. El Zein, S.E. Colby, W. Zhou, K.P. Shelnutt, G.W. Greene, T.M. Horacek, et al., Food insecurity is associated with increased risk of obesity in US college students, Curr. Dev. Nutr. 4 (8) (2020), https://doi.org/10.1093/cdn/nzaa120 nzaa120.
[50] C.W. Leung, J.A. Wolfson, J. Lahne, M.R. Barry, N. Kasper, A.J. Cohen, Associations between food security status and diet-related outcomes among students at a large, public Midwestern University, J. Acad. Nutr. Diet. 119 (10) (2019) 1623–1631, https://doi.org/10.1016/j.jand.2019.06.251.
[51] J. Mei, A.P. Fulay, J.A. Wolfson, C.W. Leung, Food insecurity and dietary intake among college students with unlimited meal plans at a

large, J. Acad. Nutr. Diet. 121 (11) (2021) 2267–2274, https://doi.org/10.1016/j.jand.2021.04.009. Midwestern University.
[52] T.A. Marshall, B. Laurence, F. Qian, G. Robinson-Warner, N. Handoo, C. Anderson, Food insecurity is associated with lower diet quality among dental students, J. Dent. Educ. (2023), https://doi.org/10.1002/jdd.13344.
[53] T.M. Levy, R.D. Williams, M. Odum, J.M. Housman, J.D. McDonald, Impact of COVID-19 stress on food insecurity and fruit and vegetable consumption among college students, J. Am. Coll. Health (2022), https://doi.org/10.1080/07448481.2022.2098033, 1–8.
[54] M. Bruening, S. Brennhofer, I. van Woerden, M. Todd, M. Laska, Factors related to the high rates of food insecurity among diverse, urban college freshmen, J. Acad. Nutr. Diet. 116 (9) (2016) 1450–1457, https://doi.org/10.1016/j.jand.2016.04.004.
[55] E. Mirabitur, K.E. Peterson, C. Rathz, S. Matlen, N. Kasper, Predictors of college-student food security and fruit and vegetable intake differ by housing type, J. Am. Coll. Health. 64 (7) (2016) 555–564, https://doi.org/10.1080/07448481.2016.1192543.
[56] F.B. Silva, D.E. Osborn, M.R. Owens, T. Kirkland, C.E. Moore, M.A. Patterson, et al., Influence of COVID-19 pandemic restrictions on college students' dietary quality and experience of the food environment, Nutrients 13 (8) (2021) 2790, https://doi.org/10.3390/nu13082790.
[57] K.J. Aldaz, S.O. Flores, R.M. Ortiz, L.K. Diaz Rios, J. Dhillon, A cross-sectional analysis of food perceptions, food preferences, diet quality, and health in a food desert campus, Nutrients 14 (24) (2022) 5215, https://doi.org/10.3390/nu14245215.
[58] J.D. Sackey, K. Pike, P. Rothpletz-Puglia, R. Brody, R. Touger-Decker, Food insecurity among health sciences graduate students at a large Northeastern University, J. Nutr. Educ. Behav. 53 (5) (2021) 428–433, https://doi.org/10.1016/j.jneb.2020.11.003.
[59] L. Steinfeldt, J. Anand, T. Murayi, Food reporting patterns in the USDA automated multiple-pass method, Procedia, Food Sci 2 (2013) 145–156, https://doi.org/10.1016/j.profoo.2013.04.022.
[60] J.M. Conway, L.A. Ingwersen, A.J. Moshfegh, Accuracy of dietary recall using the USDA five-step multiple-pass method in men: an observational validation study, J. Am. Diet Assoc. 104 (4) (2004) 595–603, https://doi.org/10.1016/j.jada.2004.01.007, 2004.
[61] M.D. Radtke, G.M. Chodur, M.C.S. Bissell, L.C. Kemp, V. Medici, F.M. Steinberg, et al., Validation of diet ID^{TM} in predicting nutrient intake compared to dietary recalls, skin carotenoid scores, and plasma carotenoids in university students, Nutrients 15 (2) (2023) 409, https://doi.org/10.3390/nu15020409.
[62] S. Jun, A.E. Cowan, K.W. Dodd, J.A. Tooze, J.J. Gahche, H.A. Eicher-Miller, et al., Association of food insecurity with dietary intakes and nutritional biomarkers among US children, National Health and Nutrition Examination Survey (NHANES) 2011-2016, Am. J. Clin. Nutr. 114 (3) (2021) 1059–1069, https://doi.org/10.1093/ajcn/nqab113.
[63] H.A. Eicher-Miller, A.C. Mason, C.M. Weaver, G.P. McCabe, C.J. Boushey, Food insecurity is associated with iron deficiency anemia in US adolescents, Am. J. Clin. Nutr. 90 (5) (2009) 1358–1371, https://doi.org/10.3945/ajcn.2009.27886.
[64] E. Rantala, A. Balatsas-Lekkas, N. Sozer, K. Pennanen, Overview of objective measurement technologies for nutrition research, food-related consumer and marketing research, Trends Food Sci. Technol. 125 (2022) 100–113, https://doi.org/10.1016/j.tifs.2022.05.006.
[65] M.L. Jobarteh, M.A. McCrory, B. Lo, M. Sun, E. Sazonov, A.K. Anderson, et al., Development and validation of an objective, passive dietary assessment method for estimating food and nutrient intake in households in low- and middle-income countries: A study protocol, Curr. Dev. Nutr. 4 (2) (2020), https://doi.org/10.1093/cdn/nzaa020 nzaa020.
[66] M.D. Radtke, S.J. Pitts, L. Jahns, G.C. Firnhaber, B.M. Loofbourrow, A. Zeng, et al., Criterion-related validity of spectroscopy-based skin carotenoid measurements as a proxy for fruit and vegetable intake: A systematic review, Adv. Nutr. 11 (5) (2020) 1282–1299, https://doi.org/10.1093/advances/nmaa054.
[67] N.A. Kong, F.M. Moy, S.H. Ong, G.A. Tahir, C.K. Loo, MyDietCam: development and usability study of a food recognition integrated dietary monitoring smartphone application, Digit Health 9 (2023) 20552076221149320, https://doi.org/10.1177/20552076221149320.
[68] B.J. Mortazavi, R. Gutierrez-Osuna, A review of digital innovations for diet monitoring and precision nutrition, J. Diabetes Sci. Technol. 17 (1) (2023) 217–223, https://doi.org/10.1177/19322968211041356.
[69] A.E. Mohr, P. Jasbi, K.B. Vander Wyst, I. van Woerden, X. Shi, H. Gu, et al., Association of food insecurity on gut microbiome and metabolome profiles in a diverse college-based sample, Sci. Rep. 12 (1) (2022) 14358, https://doi.org/10.1038/s41598-022-18515-y.
[70] Q. Tang, G. Jin, G. Wang, T. Liu, X. Liu, B. Wang, et al., Current sampling methods for gut microbiota: A call for more precise devices, Front Cell Infect. Microbiol. 10 (2020) 151, https://doi.org/10.3389/fcimb.2020.00151.
[71] T.J. Ge, V.N. Rahimzadeh, K. Mintz, W.G. Park, N. Martinez-Martin, J.C. Liao, et al., Passive monitoring by smart toilets for precision health, Sci. Transl. Med. 15 (681) (2023), https://doi.org/10.1126/scitranslmed.abk3489 eabk3489.
[72] P.Y. Tan, J.B. Moore, L. Bai, G. Tang, Y.Y. Gong, In the context of the triple burden of malnutrition: A systematic review of gene-diet interactions and nutritional status, Crit. Rev. Food Sci. Nutr. (2022) 1–29, https://doi.org/10.1080/10408398.2022.2131727.
[73] A. Astrup, S. Bügel, Overfed but undernourished: recognizing nutritional inadequacies/deficiencies in patients with overweight or obesity, Int. J. Obes. (Lond.). 43 (2) (2019) 219–232, https://doi.org/10.1038/s41366-018-0143-9.
[74] N. Darmon, E.L. Ferguson, A. Briend, A cost constraint alone has adverse effects on food selection and nutrient density: an analysis of human diets by linear programming, J. Nutr. 132 (12) (2002) 3764–3771, https://doi.org/10.1093/jn/132.12.3764.
[75] A. Huelskamp, J. Waity, J. Russell, Effects of campus food insecurity on obesogenic behaviors in college students, J. Am. Coll. Health. 69 (5) (2021) 572–575, https://doi.org/10.1080/07448481.2019.1684298.
[76] M.A. Gosse, How accurate is self-reported BMI? Nutr. Bull. 39 (1) (2014) 105–114, https://doi.org/10.1111/nbu.12075.
[77] A.A. Lyons, J. Park, C.H. Nelson, Food insecurity and obesity: a comparison of self-reported and measured height and weight, Am. J. Public Health. 98 (4) (2008) 751–757, https://doi.org/10.2105/AJPH.2006.093211.
[78] M.L. Frank, G.B. Sprada, K.V. Hultstand, C.E. West, J.A. Livingston, A.F. Sato, Toward a deeper understanding of food insecurity among college students: examining associations with emotional eating and biological sex, J. Am. Coll. Health (2021) 1–9, https://doi.org/10.1080/07448481.2021.1936536.
[79] M. Umeda, S.L. Ullevig, E. Chung, Y. Kim, T.J. Escobedo, C.J. Zeitz, Depression mediates the relationship between food insecurity and pain interference in college students, Int. J. Environ. Res. Public Health. 18 (1) (2020) 78, https://doi.org/10.3390/ijerph18010078.
[80] A. El Zein, K.P. Shelnutt, S. Colby, M.J. Vilaro, W. Zhou, G. Greene, et al., Prevalence and correlates of food insecurity among U.S. college students: a multi-institutional study, BMC Public Health 19 (1) (2019) 660, https://doi.org/10.1186/s12889-019-6943-6.
[81] C.P. Bailey, S. Sharma, C.D. Economos, E. Hennessy, C. Simon, D.P. Hatfield, College campuses' influence on student weight and related behaviours: a review of observational and intervention research, Obes. Sci. Pract. 6 (6) (2020) 694–707, https://doi.org/10.1002/osp4.445.
[82] United States Department of Agriculture, the United States Department of Health and Human Services, 2020-2025. Dietary guidelines for Americans, 9th ed., December 2020. Available from: https://www.dietaryguidelines.gov/sites/default/files/2020-12/Dietary_Guidelines_for_Americans_2020-2025.pdf. (Accessed 25 March 2023).
[83] A. Meza, E. Altman, S. Martinez, C.W. Leung, "It's a Feeling That One Is Not Worth Food": a Qualitative Study Exploring the Psychosocial Experience and Academic Consequences of Food Insecurity Among College Students, J. Acad. Nutr. Diet. 119 (10) (2019) 1713–1721, https://doi.org/10.1016/j.jand.2018.09.006, e1.
[84] M.D. Majmudar, S. Chandra, K. Yakkala, S. Kennedy, A. Agrawal, M. Sippel, et al., Smartphone camera based assessment of adiposity: a validation study, NPJ Digit Med 5 (1) (2022) 79, https://doi.org/10.1038/s41746-022-00628-3.
[85] Y. Lee, C. Howe, S. Mishra, D.S. Lee, M. Mahmood, M. Piper, et al., Wireless, intraoral hybrid electronics for real-time quantification of sodium intake toward hypertension management, Proc. Natl. Acad. Sci. U S A. 115 (21) (2018) 5377–5382, https://doi.org/10.1073/pnas.1719573115.
[86] S. Huhn, M. Axt, H.C. Gunga, M.A. Maggioni, S. Munga, D. Obor, et al., The impact of wearable technologies in Health Research: scoping review, JMIR MHealth UHealth 10 (1) (2022) e34384, https://doi.org/10.2196/34384.

[87] R.A.H. Adan, E.M. van der Beek, J.K. Buitelaar, J.F. Cryan, J. Hebebrand, S. Higgs, et al., Nutritional psychiatry: towards improving mental health by what you eat, Eur. Neuropsychopharmacol. 29 (12) (2019) 1321–1332, https://doi.org/10.1016/j.euroneuro.2019.10.011.

[88] J. Godos, W. Currenti, D. Angelino, P. Mena, S. Castellano, F. Caraci, et al., Diet and mental health: review of the recent updates on molecular mechanisms, Antioxidants (Basel) 9 (4) (2020) 346, https://doi.org/10.3390/antiox9040346.

[89] C.A. Myers, Food insecurity and psychological distress: a review of the recent literature, Curr. Nutr. Rep. 9 (2) (2020) 107–118, https://doi.org/10.1007/s13668-020-00309-1.

[90] E. Diener, D. Wirtz, W. Tov, C. Kim-Prieto, D.W. Choi, S. Oishi, et al., New well-being measures: short scales to assess flourishing and positive and negative feelings, Soc. Indic. Res. 97 (2) (2010) 143–156, https://doi.org/10.1007/s11205-009-9493-y.

[91] C. Marmolejo, J.E. Banta, G. Siapco, M.B. Baba Djara, Examining the association of student mental health and food security with college GPA, J. Am. Coll. Health (2022) 1–7, https://doi.org/10.1080/07448481.2022.2058327.

[92] R. DeBate, D. Himmelgreen, J. Gupton, J.N. Heuer, Food insecurity, well-being, and academic success among college students: implications for post COVID-19 pandemic programming, Ecol, Food Nutr 60 (5) (2021) 564–579, https://doi.org/10.1080/03670244.2021.1954511.

[93] M. Sunderland, M.J. Hobbs, T.M. Anderson, G. Andrews, Psychological distress across the lifespan: examining age-related item bias in the Kessler 6 Psychological Distress Scale, Int. Psychogeriatr. 24 (2) (2012) 231–242, https://doi.org/10.1017/S1041610211001852.

[94] M.E. Haskett, S. Majumder, D. Kotter- Grühn, I. Gutierrez, The role of university students' wellness in links between homelessness, food insecurity, and academic success, J. Soc. Distress Homelessness. 30 (1) (2021) 59–65, https://doi.org/10.1080/10530789.2020.1733815.

[95] P.G. Guzman, J.E. Lange, A.C. McClain, The association between food security status and psychological distress and loneliness among full-time undergraduate students at a minority-serving institution, Int. J. Environ. Res. Public Health. 19 (22) (2022) 15245, https://doi.org/10.3390/ijerph192215245.

[96] M.B. Becerra, B.J. Becerra, Psychological distress among college students: role of food insecurity and other social determinants of mental health, Int. J. Environ. Res. Public Health 17 (11) (2020) 4118, https://doi.org/10.3390/ijerph17114118.

[97] C. Mahoney, B.J. Becerra, D. Arias, J.E. Romano, M.B. Becerra, 'We've Always Been Kind of Kicked to the Curb': A mixed-methods assessment of discrimination experiences among college students, Int. J. Environ. Res. Public Health. 19 (15) (2022) 9607, https://doi.org/10.3390/ijerph19159607.

[98] A. ElTohamy, J.J. Wang, J.A. Chen, C. Stevens, C.H. Liu, Association between college course delivery model and rates of psychological distress during the COVID-19 pandemic, JAMA Netw. Open. 5 (11) (2022) e2244270, https://doi.org/10.1001/jamanetworkopen.2022.44270.

[99] R.L. Hagedorn, M.D. Olfert, L. MacNell, B. Houghtaling, L.B. Hood, M.R. Savoie Roskos, et al., College student sleep quality and mental and physical health are associated with food insecurity in a multi-campus study, Public Health Nutr 24 (13) (2021) 4305–4312, https://doi.org/10.1017/S1368980021001191.

[100] K.E. Coakley, S. Cargas, M. Walsh-Dilley, H. Mechler, Basic needs insecurities are associated with anxiety, depression, and poor health among university students in the State of New Mexico, J. Community Health 47 (3) (2022) 454–463, https://doi.org/10.1007/s10900-022-01073-9.

[101] R.A. Wattick, R.L. Hagedorn, M.D. Olfert, Relationship between diet and mental health in a Young adult Appalachian college population, Nutrients 10 (8) (2018) 957, https://doi.org/10.3390/nu10080957.

[102] K. Kroenke, R.L. Spitzer, J.B. Williams, The PHQ-9: validity of a brief depression severity measure, J. Gen. Intern. Med. 16 (9) (2001) 606–613, https://doi.org/10.1046/j.1525-1497.2001.016009606.x.

[103] L. Neal, V.A. Zigmont, Undergraduate food insecurity, mental health, and substance use behaviors, Nutr. Health (2022) 2601060221142669, https://doi.org/10.1177/02601060221142669.

[104] I.G. Raskind, R. Haardörfer, C.J. Berg, Food insecurity, psychosocial health and academic performance among college and university students in Georgia, USA, Public Health Nutr 22 (3) (2019) 476–485, https://doi.org/10.1017/S1368980018003439.

[105] N. Reeder, P. Tapanee, A. Persell, T. Tolar-Peterson, Food insecurity, depression, and race: correlations observed among college students at a university in the Southeastern United States, Int. J. Environ. Res. Public Health. 17 (21) (2020) 8268, https://doi.org/10.3390/ijerph17218268.

[106] K.K. Diamond, M.J. Stebleton, R.C. delMas, Exploring the relationship between food insecurity and mental health in an undergraduate student population, J. Stud. Aff. Res. Pract. 57 (5) (2020) 546–560, https://doi.org/10.1080/19496591.2019.1679158.

[107] Y. Kim, J. Murphy, Mental health, food insecurity, and economic hardship among college students during the COVID-19 pandemic, Health Soc. Work. 48 (2) (2023) 124–132, https://doi.org/10.1093/hsw/hlad006.

[108] J.A. Coffino, S.P. Spoor, R.D. Drach, J.M. Hormes, Food insecurity among graduate students: prevalence and association with depression, anxiety and stress, Public Health Nutr 24 (7) (2021) 1889, https://doi.org/10.1017/S1368980020002001, 94.

[109] M. Umeda, Y. Kim, S.W. Park, E. Chung, S.L. Ullevig, Food insecurity and academic function among college students during the COVID-19 pandemic: A moderating role of the first-generation college student status, J. Am. Coll. Health (2023) 1–7, https://doi.org/10.1080/07448481.2023.2185076.

[110] M. Cockerham, S. Camel, L. James, D. Neill, Food insecurity in baccalaureate nursing students: A cross-sectional survey, J. Prof. Nurs. 37 (2) (2021) 249–254, https://doi.org/10.1016/j.profnurs.2020.12.015.

[111] C.L. Harris, S. Haack, Z. Miao, Everyday discrimination is a stronger predictor of eating competence than food insecurity or perceived stress in college students amidst COVID-19, Appetite 179 (2022) 106300, https://doi.org/10.1016/j.appet.2022.106300.

[112] M. Boukhechba, A.R. Daros, K. Fua, P.I. Chow, B.A. Teachman, L.E. Barnes, DemonicSalmon: monitoring mental health and social interactions of college students using smartphones, Smart Health 9–10 (10) (2018) 192–203, https://doi.org/10.1016/j.smhl.2018.07.005.

[113] M.M. Ng, J. Firth, M. Minen, J. Torous, User engagement in mental health apps: a review of measurement, reporting, and validity, Psychiatr. Serv. 70 (7) (2019) 538–544, https://doi.org/10.1176/appi.ps.201800519.

[114] I. Nicolaidou, L. Aristeidis, L. Lambrinos, A gamified app for supporting undergraduate students' mental health: A feasibility and usability study, Digit Health 8 (2022) 20552076221109059, https://doi.org/10.1177/20552076221109059.

[115] M.D. Nemesure, M.V. Heinz, R. Huang, N.C. Jacobson, Predictive modeling of depression and anxiety using electronic health records and a novel machine learning approach with artificial intelligence, Sci. Rep. 11 (1) (2021) 1980, https://doi.org/10.1038/s41598-021-81368-4.

[116] I.B. Hickie, E.M. Scott, S.P. Cross, F. Iorfino, T.A. Davenport, A.J. Guastella, et al., Right care, first time: a highly personalised and measurement-based care model to manage youth mental health, Med. J. Aust. 211 (9) (2019) S3–S46, https://doi.org/10.5694/mja2.50383. Suppl 9.

[117] D. Yikealo, B. Yemane, I. Karvinen, The level of academic and environmental stress among college students: A case in the College of Education, Open J. Soc. Sci. 06 (11) (2018) 40–57, https://doi.org/10.4236/jss.2018.611004.

[118] L. Sominsky, S.J. Spencer, Eating behavior and stress: a pathway to obesity, Front Psychol 5 (2014) 434, https://doi.org/10.3389/fpsyg.2014.00434.

[119] A.L. Richards, B. Specker, Evaluating hours of sleep and perceived stress on dietary cognitive restraint in a survey of college students, J. Am. Coll. Health. 68 (8) (2020) 824–831, https://doi.org/10.1080/07448481.2019.1618312.

[120] S.L. Matias, J. Rodriguez-Jordan, M. McCoin, Integrated nutrition and culinary education in response to food insecurity in a public university, Nutrients 13 (7) (2021) 2304, https://doi.org/10.3390/nu13072304.

[121] N. Guerithault, S.M. McClure, C.O. Ojinnaka, B.B. Braden, M. Bruening, Resting-state functional connectivity differences in college students with and without food insecurity, Nutrients 14 (10) (2022) 2064, https://doi.org/10.3390/nu14102064.

[122] A.D. Crosswell, K.G. Lockwood, Best practices for stress measurement: how to measure psychological stress in health research, Health Psychol. Open. 7 (2) (2020) 2055102920933072, https://doi.org/10.1177/2055102920933072.

[123] A. Testa, D.B. Jackson, Adverse childhood experiences and food insecurity in adulthood: evidence from the national longitudinal study of adolescent to adult health, J. Adolesc. Health. 67 (2) (2020) 218–224, https://doi.org/10.1016/j.jadohealth.2020.02.002.
[124] E.K. Adam, M.E. Quinn, R. Tavernier, M.T. McQuillan, K.A. Dahlke, K.E. Gilbert, Diurnal cortisol slopes and mental and physical health outcomes: A systematic review and meta-analysis, Psychoneuroendocrinology 83 (2017) 25–41, https://doi.org/10.1016/j.psyneuen.2017.05.018.
[125] H.Y.Y. Nyein, M. Bariya, B. Tran, C.H. Ahn, B.J. Brown, W. Ji, et al., A wearable patch for continuous analysis of thermoregulatory sweat at rest, Nat. Commun. 12 (1) (2021) 1823, https://doi.org/10.1038/s41467-021-22109-z.
[126] Y. Li, W. Jia, N. Yan, Y. Hua, T. Han, J. Yang, et al., Associations between chronic stress and hair cortisol in children: A systematic review and meta-analysis, J. Affect Disord. 329 (2023) 438–447, https://doi.org/10.1016/j.jad.2023.02.123.
[127] J. Ling, L.B. Robbins, D. Xu, Food security status and hair cortisol among low-income mother-child dyads, West J. Nurs. Res. 41 (12) (2019) 1813–1828, https://doi.org/10.1177/0193945919867112.
[128] M. Montoya, B.N. Uchino, Social support and telomere length: a meta-analysis, J. Behav. Med. 46 (4) (2023) 556–565, https://doi.org/10.1007/s10865-022-00389-0.
[129] M. Ding, M.K. Keiley, K.B. Garza, P.A. Duffy, C.A. Zizza, Food insecurity is associated with poor sleep outcomes among US adults, J. Nutr. 145 (3) (2015) 615–621, https://doi.org/10.3945/jn.114.199919.
[130] H. Binks, G.E. Vincent, C. Gupta, C. Irwin, S. Khalesi, Effects of diet on sleep: A narrative review, Nutrients 12 (4) (2020) 936, https://doi.org/10.3390/nu12040936.
[131] F. Wang, É. Bíró, Determinants of sleep quality in college students: A literature review, Explore (NY) 17 (2) (2021) 170–177, https://doi.org/10.1016/j.explore.2020.11.003.
[132] M.B. Becerra, B.S. Bol, R. Granados, C. Hassija, Sleepless in school: the role of social determinants of sleep health among college students, J. Am. Coll. Health 68 (2) (2020) 185–191, https://doi.org/10.1080/07448481.2018.1538148.
[133] D.J. Buysse, C.F. Reynolds III, T.H. Monk, S.R. Berman, D.J. Kupfer, The Pittsburgh Sleep Quality Index: a new instrument for psychiatric practice and research, Psychiatry Res 28 (2) (1989) 193–213, https://doi.org/10.1016/0165-1781(89)90047-4.
[134] C.V. Senaratna, J.L. Perret, M.C. Matheson, C.J. Lodge, A.J. Lowe, R. Cassim, et al., Validity of the Berlin questionnaire in detecting obstructive sleep apnea: A systematic review and meta-analysis, Sleep Med. Rev. 36 (2017) 116–124, https://doi.org/10.1016/j.smrv.2017.04.001.
[135] W.M. Troxel, A. Haas, B. Ghosh-Dastidar, A.S. Richardson, L. Hale, D.J. Buysse, et al., Food insecurity is associated with objectively measured sleep problems, Behav. Sleep Med. 18 (6) (2020) 719–729, https://doi.org/10.1080/15402002.2019.1669605.
[136] S. Ancoli-Israel, R. Cole, C. Alessi, M. Chambers, W. Moorcroft, C.P. Pollak, The role of Antigraphy in the study of sleep and circadian rhythms, Sleep 26 (3) (2003) 342–392, https://doi.org/10.1093/sleep/26.3.342.
[137] A.R. Weiss, N.L. Johnson, N.A. Berger, S. Redline, Validity of activity-based devices to estimate sleep, J. Clin. Sleep Med. 6 (4) (2010) 336–342, https://doi.org/10.5664/jcsm.27874.
[138] M. Asgari Mehrabadi, I. Azimi, F. Sarhaddi, A. Axelin, H. Niela-Vilén, S. Myllyntausta, et al., Sleep tracking of a commercially available smart ring and Smartwatch against medical-grade actigraphy in everyday settings: instrument validation study, JMIR MHealth UHealth 8 (10) (2020) e20465, https://doi.org/10.2196/20465.
[139] M. de Zambotti, L. Rosas, I.M. Colrain, F.C. Baker, The sleep of the ring: comparison of the OURA sleep tracker against polysomnography, Behav. Sleep Med. 17 (2) (2019) 124–136, https://doi.org/10.1080/15402002.2017.1300587.
[140] M. Altini, H. Kinnunen, The promise of sleep: A multi-sensor approach for accurate sleep stage detection using the Oura ring, Sensors (Basel). 21 (13) (2021) 4302, https://doi.org/10.3390/s21134302.
[141] R. Danzig, M. Wang, A. Shah, L.M. Trotti, The wrist is not the brain: estimation of sleep by clinical and consumer wearable actigraphy devices is impacted by multiple patient- and device-specific factors, J. Sleep Res. 29 (1) (2020) e12926, https://doi.org/10.1111/jsr.12926.
[142] M.T. Bianchi, K.L. Williams, S. McKinney, J.M. Ellenbogen, The subjective-objective mismatch in sleep perception among those with insomnia and sleep apnea, J. Sleep Res. 22 (5) (2013) 557–568, https://doi.org/10.1111/jsr.12046.
[143] D. O'Donnell, E.J. Silva, M. Münch, J.M. Ronda, W. Wang, J.F. Duffy, Comparison of subjective and objective assessments of sleep in healthy older subjects without sleep complaints, J. Sleep Res. 18 (2) (2009) 254–263, https://doi.org/10.1111/j.1365-2869.2008.00719.x.
[144] J.M. Nagata, K. Palar, H.C. Gooding, A.K. Garber, J.L. Tabler, H.J. Whittle, et al., Food insecurity, sexual risk, and substance use in Young adults, J. Adolesc. Health. 68 (1) (2021) 169–177, https://doi.org/10.1016/j.jadohealth.2020.05.038.
[145] K.S. Demartini, K.B. Carey, Optimizing the use of the AUDIT for alcohol screening in college students, Psychol. Assess. 24 (4) (2012) 954–963, https://doi.org/10.1037/a0028519.
[146] L. Devos-Comby, J.E. Lange, Standardized measures of alcohol-related problems: a review of their use among college students, Psychol. Addict, Behav 22 (3) (2008) 349–361, https://doi.org/10.1037/0893-164X.22.3.349.
[147] M. Jensen, A. Hussong, Text message content as a window into college student drinking: development and initial validation of a dictionary of "alcohol talk", Int. J. Behav. Dev. 45 (1) (2021) 3–10, https://doi.org/10.1177/0165025419889175.
[148] V.M. Hazzard, K.A. Loth, L. Hooper, C.B. Becker, Food insecurity and eating disorders: a review of emerging evidence, Curr. Psychiatry Rep. 22 (12) (2020) 74, https://doi.org/10.1007/s11920-020-01200-0.
[149] M.R. Barry, K.R. Sonneville, C.W. Leung, Students with food insecurity are more likely to screen positive for an eating disorder at a large, public university in the midwest, J. Acad. Nutr. Diet. 121 (6) (2021) 1115–1124, https://doi.org/10.1016/j.jand.2021.01.025.
[150] M.F. Royer, C.O. Ojinnaka, M. Bruening, Food insecurity is related to disordered eating behaviors among college students, J. Nutr. Educ. Behav. 53 (11) (2021) 951–956, https://doi.org/10.1016/j.jneb.2021.08.005.
[151] A.C. Grammer, E.E. Fitzsimmons-Craft, O. Laing, B. De Pietro, D.E. Wilfley, Eating disorders on college campuses in the United States: current insight on screening, prevention, and treatment, Curr. Psychopharmacol. 9 (2) (2020) 91–102, https://doi.org/10.2174/2211556009999200416153022.
[152] E. Stice, H. Shaw, Eating disorders: insights from imaging and behavioral approaches to treatment, J. Psychopharmacol. 31 (11) (2017) 1485–1495, https://doi.org/10.1177/0269881117722999.
[153] C. Prickett, L. Brennan, R. Stolwyk, Examining the relationship between obesity and cognitive function: a systematic literature review, Obes. Res. Clin. Pract. 9 (2) (2015) 93–113, https://doi.org/10.1016/j.orcp.2014.05.001.
[154] M. Na, N. Dou, N. Ji, D. Xie, J. Huang, K.L. Tucker, et al., Food insecurity and cognitive function in middle to older adulthood: A systematic review, Adv Nutr 11 (3) (2020) 667–676, https://doi.org/10.1093/advances/nmz122.
[155] M.F. Royer, N. Guerithault, B.B. Braden, M.N. Laska, M. Bruening, Food insecurity is associated with cognitive function: A systematic review of findings across the life course, Int. J. Transl. Med. 1 (3) (2021) 205–222, https://doi.org/10.3390/ijtm1030015.
[156] D. Gallegos, A. Eivers, P. Sondergeld, C. Pattinson, Food insecurity and child development: A state-of-the-art review, Int. J. Environ. Res. Public Health. 18 (17) (2021) 8990, https://doi.org/10.3390/ijerph18178990.
[157] X. Gao, T. Scott, L.M. Falcon, P.E. Wilde, K.L. Tucker, Food insecurity and cognitive function in Puerto Rican adults, Am. J. Clin. Nutr. 89 (4) (2009) 1197–1203, https://doi.org/10.3945/ajcn.2008.26941.
[158] E. Frith, P.D. Loprinzi, Food insecurity and cognitive function in older adults: brief report, Clin. Nutr. 37 (5) (2018) 1765–1768, https://doi.org/10.1016/j.clnu.2017.07.001.
[159] E.T. Portela-Parra, C.W. Leung, Food insecurity is associated with lower cognitive functioning in a national sample of older adults, J. Nutr. 149 (10) (2019) 1812–1817, https://doi.org/10.1093/jn/nxz120.
[160] S.J. Holdsworth, R. Bammer, Magnetic resonance imaging techniques: fMRI, DWI, and PWI, Semin. Neurol. 28 (4) (2008) 395–406, https://doi.org/10.1055/s-0028-1083697.
[161] T.E. Wilens, N.W. Carrellas, M. Martelon, A.M. Yule, R. Fried, R. Anselmo, et al., Neuropsychological functioning in college students who misuse prescription stimulants, Am. J. Addict. 26 (4) (2017) 379–387, https://doi.org/10.1111/ajad.12551.
[162] M. Arain, M. Haque, L. Johal, P. Mathur, W. Nel, A. Rais, et al., Maturation of the adolescent brain, Neuropsychiatr. Dis. Treat. 9 (2013) 449–461, https://doi.org/10.2147/NDT.S39776.

[163] R.R. Weaver, N.A. Vaughn, S.P. Hendricks, P.E. McPherson-Myers, Q. Jia, S.L. Willis, et al., University student food insecurity and academic performance, J. Am. Coll. Health. 68 (7) (2020) 727–733, https://doi.org/10.1080/07448481.2019.1600522.
[164] K. Camelo, M. Elliott, Food insecurity and academic achievement among college students at a Public University in The United States, J. Coll. Stud. Dev. 60 (3) (2019) 307–318, https://doi.org/10.1353/csd.2019.0028.
[165] S.M. Martinez, E.A. Frongillo, C.W. Leung, L. Ritchie, No food for thought: food insecurity is related to poor mental health and lower academic performance among students in California's public university system, J. Health Psychol. 25 (12) (2020) 1930, https://doi.org/10.1177/1359105318783028. –9.
[166] M.R. Silva, W.L. Kleinert, A.V. Sheppard, K.A. Cantrell, D.J. Freeman-Coppadge, E. Tsoy, et al., The relationship between food security, housing stability, and school performance among college students in an urban university, J. Coll. Stud. Retent. Res. Theor. Pract. 19 (3) (2017) 284–299, https://doi.org/10.1177/1521025115621918.
[167] A. Hege, T. Stephenson, M. Pennell, B. Revlett, C. VanMeter, D. Stahl, et al., College food insecurity: implications on student success and applications for future practice, J. Stud. Aff. Res. Pract. 58 (1) (2021) 44–61, https://doi.org/10.1080/19496591.2020.1726359.
[168] E. Phillips, A. McDaniel, A. Croft, Food insecurity and academic disruption among college students, J. Stud. Aff. Res. Pract. 55 (4) (2018) 353–372, https://doi.org/10.1080/19496591.2018.1470003.
[169] I. van Woerden, D. Hruschka, M. Bruening, Food insecurity negatively impacts academic performance, J. Public Aff. 19 (3) (2019), https://doi.org/10.1002/pa.1864, 2019.
[170] S. Davinelli, S. Ali, V. Solfrizzi, G. Scapagnini, G. Corbi, Carotenoids and cognitive outcomes: A meta-analysis of randomized intervention trials, Antioxidants (Basel) 10 (2) (2021) 223, https://doi.org/10.3390/antiox10020223.
[171] A.L. Macready, O.B. Kennedy, J.A. Ellis, C.M. Williams, J.P.E. Spencer, L.T. Butler, Flavonoids and cognitive function: a review of human randomized controlled trial studies and recommendations for future studies, Genes. Nutr. 4 (4) (2009) 227–242, https://doi.org/10.1007/s12263-009-0135-4.
[172] Y.C. Probst, V.X. Guan, K. Kent, Dietary phytochemical intake from foods and health outcomes: a systematic review protocol and preliminary scoping, BMJ, (Open). 7 (2) (2017) e013337, https://doi.org/10.1136/bmjopen-2016-013337.
[173] E.E. Noble, T.M. Hsu, S.E. Kanoski, Gut to brain dysbiosis: mechanisms linking western diet consumption, the microbiome, and cognitive impairment, Front Behav. Neurosci. 11 (2017) 9, https://doi.org/10.3389/fnbeh.2017.00009.
[174] A.G.M. Brown, L.E. Esposito, R.A. Fisher, H.L. Nicastro, D.C. Tabor, J.R. Walker, Food insecurity and obesity: research gaps, opportunities, and challenges, Transl. Behav. Med. 9 (5) (2019) 980–987, https://doi.org/10.1093/tbm/ibz117.
[175] L. Jomaa, M. Diab-El-Harake, S. Kharroubi, L. Mattar, Associations between food literacy and food insecurity among college students in Lebanon: A cross-sectional study, Curr. Dev. Nutr. 6 (1) (2022) 120, https://doi.org/10.1093/cdn/nzac051.036.
[176] L.R. Henry, Understanding Food Insecurity among College Students: experience, motivation, and local solutions, Ann. Anthropol. Pract. 41 (1) (2017) 6–19, https://doi.org/10.1111/napa.12108.
[177] J.T. McGuirt, S.B. Jilcott Pitts, J.D. Labban, E.T. Anderson Steeves, L. Haynes-Maslow, S. Henry, et al., Evidence of geospatial and socioeconomic disparities in access to online grocery shopping for fresh and frozen produce in North Carolina, J. Acad. Nutr. Diet. 122 (11) (2022) 2106, https://doi.org/10.1016/j.jand.2022.05.008, 14.