Food insecurity and the consumption of plant-centered meals and high sodium foods among students at three large state universities

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Running head: Food insecurity and plant/high sodium foods

Word count (structured abstract): 150 words (max: 150 words)

Text (not including tables/figures, references): 5,178 (max: 4,000-6,000 words)

Table(s)/figure(s): 2 tables; 2 figures

References: 73 references

Journal: *Journal of American College Health*

Category: Research Article

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Funding: This project was supported in part by funding from a Centers for Disease Control and Prevention cooperative agreement (U58DP000020), awarded to the Los Angeles County Department of Public Health's Division of Chronic Disease and Injury Prevention.

Disclosure statement: The authors have no competing interests to declare.

Data availability: De-identified data are available upon request if the request is reasonable and adheres to the study's human subjects protection standards. All data inquiries can be submitted to the corresponding author.

Abstract

Objective: To examine the associations between food insecurity and plant-centered meal consumption and other sodium-related dietary behaviors among university students.

Methods: A web-based survey of three California State University students was conducted between August 2018 to May 2019. Multivariable logistic regressions examined the associations between food insecurity and four sodium-related dietary behaviors. Interaction terms were introduced to assess if race/ethnicity moderated these associations.

Results: High food insecurity was associated with increased odds of reporting 'likely to order' plant-centered meals (AOR=1.55, 95% CI=1.16-2.05). Moderate food insecurity was associated with increased odds of frequently eating processed foods (AOR=1.40, 95% CI=1.13-1.74). No moderation effects were found for race/ethnicity.

Conclusions: University students with high food insecurity appeared receptive to ordering plant-centered meals, whereas those with moderate food insecurity consumed more processed foods. State universities should encourage and offer more low-sodium, plant-centered meal options in their food venues, on- and off-campus, to promote student health.

Keywords: Food insecurity, sodium-related dietary behaviors, plant-centered meals, university students, student health

Introduction

Diet, especially limiting salt or sodium consumption, plays a key role in preventing and controlling hypertension and other cardiovascular diseases.[1] As such, various public health efforts have sought to curb Americans' consumption of high salt/sodium foods in recent decades. They include reformulating food products to contain less salt/sodium, consumer education, and front-of-package labeling.[2] Other popular approaches include nutrition standards and other healthy food procurement practices that limit sodium, changes in the food environment, and use of behavioral economics in public/private institutional food settings.[3,4] Unfortunately, successful execution of these sodium reduction interventions is often more difficult than anticipated.[5,6] This, along with other operational challenges, may, in part, help explain why hypertension continues to be a growing public health problem in the United States (U.S.). An analysis of the National Health and Nutrition Examination Survey (NHANES) found that there was an upward trend in the age-adjusted prevalence of hypertension beginning in 2015.[7] Another study found that residents in the U.S. were increasingly at risk for cardiovascular morbidity and mortality.[8] Local trends, such as those in Los Angeles County, mirror these national findings.[9]

Policy, nutrition standards, and food procurement levers at the broader community and jurisdictional level can be leveraged to improve cardiovascular health outcomes. Yet, these levers are not typically a "one size fits all" solution, as other avenues that help individuals reduce sodium consumption are needed and should be considered. These include strategies that leverage individuals' volition when given access to healthier options (e.g., lower sodium meals) through public encouragement and/or expanding institutional offerings. Promoting and facilitating the consumption of plant-centered meals represents one such promising approach in this class of interventions. In this article, we define plant-centered meals as those that emphasize plant-

derived foods (i.e., fruits, vegetables, legumes, and similar which are naturally lower in sodium) and that minimally include foods derived from animals such as meat, dairy, and eggs. Although consumption of plant-centered meals aligns with federal recommendations on what Americans should eat and drink to maintain good health (e.g., nutrient-dense foods such as vegetables, fruits, and whole grains),[10] encouraging and helping people to consume these meal options remain difficult, in part because U.S. public health efforts have not explicitly focused on promoting this type of dietary behavior as a population health strategy for improving cardiovascular health.

Consumption of plant-centered foods may be particularly effective among young adults, a group whose risk for cardiovascular morbidity and mortality has steadily increased in recent decades.[11] For instance, shifting towards a diet characterized by plants in young to middle adulthood is associated with reduced risk of chronic conditions such as diabetes and weight gain.[12] Such shift in diet likely lowers a person's chronic disease risk by replacing the intake of calorie-dense alternatives, which are generally higher in sodium, sugar, and/or saturated fat, with plant-based options. However, it is important to consider that the nutritional value of plant-centered foods/meals can vary and that they are not always healthy. For instance, it has been documented that such foods/meals are often ultra-processed and high in sodium.[13] Nonetheless, promotion of a plant-centered diet can lead to better cardiovascular health outcomes if it emphasizes choosing naturally occurring plant foods (e.g., fresh fruits and vegetables, legumes, whole grains, etc.) that are inherently low in salt/sodium.

Helping young adults shift towards a plant-centered diet also makes planetary sense and may resonate with several values common in this age group. For example, there is growing evidence that younger populations in the U.S. and around the world have greater awareness and

anxiety about climate change and may feel a greater social responsibility to reduce their carbon footprint.[14] Compared to plant-derived foods, animal-derived counterparts (e.g., meat, dairy, eggs, fish) and/or those that are more processed are known to contribute to global warming.[15,16] Given this sensibility towards the environment, postsecondary schools, which primarily serve young adults,[17] represent an important setting where plant-centered options can be introduced and promoted in an eco-friendly way.[18] It also appears that the COVID-19 pandemic ironically played indirect roles in facilitating young adults' interest in plant-centered meals. This global public health emergency and its resulting stay-at-home restrictions led to an increase in online/hybrid learning and extra time not spent on travel.[19] A number of studies have found that the pandemic afforded students an opportunity to better manage their time[20], including more leisure time to engage in activities such as healthy cooking.[21]

Food insecurity, defined as a lack of or inability to obtain nutritious foods in a safe and socially acceptable way,[22] is another factor that may have contributed to the etiology of cardiovascular disease at the population level. For example, a recent study found that food insecurity was associated with higher salt/sodium intake among low-income groups during the pandemic.[23] Studies from before the COVID-19 public health emergency had found that people who rely on food pantries and other emergency meal services frequently consumed excess sodium.[24,25] These results, however, were not surprising, as foods offered in these settings are often highly processed and/or are shelf-stable items high in salt/sodium.[26,27]

It is also important to recognize that the burden of food insecurity is unequally distributed and has been found to vary by race/ethnicity and by different population characteristics.[28–30] University students, especially those from communities of color, are a group at relatively high risk for moderate/high food insecurity because of these differences.[31,32]

159 Collectively, emerging research underscores how the interactions between food insecurity
160 and diet can affect various groups differently. This is especially the case for groups that have
161 historically been overlooked or excluded in food and nutrition research and practice. University
162 students represent one such group; it was only about a decade ago that researchers and public
163 health professionals began to recognize that university students may be at risk for food
164 insecurity. The first study identifying them as being food insecure or at risk for hunger was
165 published in 2009.[33] Since then, other studies have provided corroborating evidence highlighting
166 inadequate access to nutritious food among this population; some have shown that this public
167 health problem is growing.[34] The COVID-19 pandemic certainly has not helped, exacerbating
168 food insecurity across all age groups.[35,36]
169 To date, only a few studies have investigated the associations between food insecurity
170 and diet quality among university students.[37,38] None have examined the relationships between
171 food insecurity and sodium-related dietary behaviors, especially as they relate to promoting
172 sodium reduction and planetary health together. Another gap in research and public health
173 practice is the dearth of data on how race/ethnicity moderates these behavioral relationships or
174 associations. Addressing these and other gaps in knowledge and practice related to the university
175 setting could help guide or increase stakeholder and decision-maker receptivity to ways in which
176 sodium reduction and planetary health can be promoted together to improve diet[16,18,39–41] and to
177 assure food security,[41] especially among university students who are most vulnerable to hunger
178 and to developing poor health because of diet-related conditions.[18,40]
179 The present study sought to address these gaps in scientific knowledge and practice by
180 examining survey responses obtained from students at three large state universities in California.
181 Through snowball recruitment, we examined the associations between food insecurity and four

sodium-related dietary behaviors: 1) ordering plant-centered meals; 2) consumption of packaged foods; 3) adding salt when preparing food; and 4) frequently eating processed foods. We hypothesized that food insecurity is associated with lower ordering of plant-centered meals, and conversely with higher consumption of packaged foods, higher frequency of adding salt when preparing foods, and higher frequency of eating processed foods. A secondary study goal was to assess whether race/ethnicity moderated these potential associations. We hypothesized that there would be racial/ethnic differences in the associations between food insecurity and the four sodium-related dietary behavioral outcomes.

Although our data were collected before the COVID-19 pandemic, they represent an important source of information on university students' nutrition status and food selection behaviors, information that was not previously available in the literature.

Methods

Study Design

The Los Angeles County Department of Public Health (DPH) collaborated with the California State University, Northridge (CSUN) to administer the California State University (CSU) Sodium Reduction Initiative survey, a web-based survey at three large state universities in Southern California. The survey took place during Fall 2018 (beginning of August 2018) to Spring 2019 (ending in May 2019) semesters. The English-language survey collected information on sodium-related knowledge and attitudes, sodium-related dietary behaviors, health status, the financial situation of the survey participants and their family, food insecurity (nutrition security status), and sociodemographics. The survey was initially conceptualized by DPH based on the state university system's internal programmatic needs, a review of existing

literature related to determinants of cardiovascular disease risk,[42] and sodium consumption,[43] as well as previously validated surveys including the Food Insecurity Experience Scale.[44] Some of the survey questions, such as those that asked about plant-centered meals and other behaviors related to sodium, were internally developed due to their novelty. However, to the extent possible, these questions were the same or similar to those asked in previous DPH studies.[45–48] CSUN researchers and faculty (including trained nutritionists and nutrition researchers) provided iterative feedback on the survey based on their expertise and knowledge of school-wide needs. The survey was initially programmed into the Qualtrics online survey software (Qualtrics Labs, Inc, Provo, Utah) and then pilot-tested with 15 California state university students (9 undergraduate students, 6 graduate students) before field administration. Minor changes to the formatting, instructions, and question wording were made to the survey based on these students' input to increase readability and comprehension. On average, the survey during this pilot phase took approximately 25 minutes to complete (range=20-35 minutes). All survey protocols and materials were reviewed and approved by Institutional Review Boards at DPH and at each of the three California state universities.

Survey Procedures

Administration

A snowball sampling approach was used to recruit survey participants from the three state universities. First, targeted emails were sent by a member of the research team to available deans, department chairs, faculty/administrators, and student organizations at each of the three universities asking them to disseminate the survey through their existing channels (e.g., via existing listservs, etc.). The initial emails sent to key university personnel and organizations

included a short description of the web-based survey, the Qualtrics link to the web-based questionnaire (including the consent form), and a request to forward the survey invitation, consent form, and questionnaire to students, faculty, and/or staff who they had emails for. This survey invitation email was then forwarded by university leadership/organizations to students, faculty, and/or staff with the email subject line "CSU SRI survey: Get a $5 Starbucks gift card by completing a Sodium Reduction Initiative Survey." Prospective survey participants who received the forwarded email and subsequently clicked on the Qualtrics survey link were presented with a consent form. Only those who consented to participate in the survey and had a university-affiliated email address were eligible to enroll/participate. The median number of minutes that it took participants to complete the ~65-item, multiple choice/response option/skip pattern web-based questionnaire was 16 minutes. All participants who completed the survey had the option of receiving a $5 electronic gift card if they wanted it.

Data Cleaning

Across the three state universities, 4,151 people who were eligible to participate in the survey (i.e., met the criteria for participation) and who received the snowball sampling email to complete the survey clicked on the link. After the data collection period ended, research staff from CSUN downloaded Qualtrics survey responses from each of the three schools into the SPSS software; the data from the three schools were then merged. Duplicate surveys, which were identified by comparing the IP addresses from the duplicate email addresses, were deleted. Many of the surveys were eliminated if the participants marked the same number on all questions or completed it in less than 5 minutes. In the present analyses, the final sample (n = 3,133, 75% of

the total eligible pool) was generated by including only those who reported being a student and had responses for the variables of interest.

Measures

Dependent Variables

Likelihood of Ordering Meal Options Centered Around Plants (Plant-Centered Meals). Due to the novelty of the study topic, the sodium-related question corresponding to this outcome variable was internally developed by project personnel working on implementing and evaluating local sodium reduction interventions based on input from trained nutritionists and nutrition researchers. Participants were asked, “How likely or unlikely would you be to order a meal option centered around plants (e.g., vegetables, whole grains, nuts, seeds, legumes, fruits, has few or no animal products [e.g., meat] and excludes or minimizes highly refined foods [e.g., bleached flour, sugar, and oil])?” Response options included “very unlikely,” “unlikely,” “likely,” and “very likely." They were dichotomized as 0=not likely (i.e., participants reported “very unlikely” or “unlikely”) and 1=*most likely* (i.e., if participants reported “likely” or “very likely”).

Consumption of Packaged Foods. This question was also internally developed by program personnel knowledgeable with implementation of local sodium reduction interventions, based on input from trained nutritionists and nutrition researchers involved in the project. Participants were given examples of packaged foods such as chips, candy bars, and microwavable meals and then asked, “Do you try to avoid or limit consuming packaged foods?” Participants had the option of answering “yes” or “no.” “Yes” responses were categorized as

0=*limits consumption of packaged foods*, whereas "no" responses were categorized as 1=*does not limit consumption of packaged foods*.

Adds Salt to Food when Cooking/Preparing Foods. This internally developed question was adapted from a question used in previous DPH studies.[46,47] Participants were asked, "Do you add salt when cooking or preparing foods in your household?" Response options included "never," "rarely," "sometimes," "often," and "always." The responses were dichotomized as 0=*not frequently* (i.e., participants reported "never" or "rarely") and 1=*frequently* (i.e., participants reported "sometimes," "often," or "always").

Frequency of Eating Processed Foods High in Salt (High Sodium Content). This question was also internally developed by project personnel working on implementing local sodium reduction interventions and vetted by trained nutritionists and nutrition researchers. Participants were asked "Do you eat processed food high in salt, including (but not limited to): snack foods (e.g., chips, crackers), soups (e.g., instant soups, ramen), baked goods (e.g., cookies, bread, buns), pizza (e.g., frozen pizza), processed cheeses, lunch meats, bacon, and sausage?" These foods were selected because they are food categories that are typically considered to be high in sodium.[49] Response options included "never," "rarely," "sometimes," "often," and "always." The responses were dichotomized as 0=*not frequently* (i.e., participants reported "never" or "rarely") and 1=*frequently* (i.e., participants reported "sometimes," "often," or "always").

Independent Variable

Food insecurity was assessed by asking participants eight questions from the validated Food Insecurity Experience Scale (FIES).[44] The questions in this scale were: 1) "You were worried you would run out of food because of a lack of money or other resources?"; 2) "You

were unable to eat healthy and nutritious food because of a lack of money or other resources?"; 3) "You ate only a few kinds of foods because of a lack of money or other resources?"; 4) "You had to skip a meal because there was not enough money or other resources to get food?"; 5) "You ate less than you thought you should because of a lack of money or other resources?"; 6) "Your household ran out of food because of a lack of money or other resources?"; 7) "You were hungry but did not eat because there was not enough money or other resources for food?"; and 8) "You went without eating for a whole day because of a lack of money or other resources?" Response options were "Yes," "No," and "Don't Know." Responses were coded as 1=*yes* and 0=*no/don't know*. The responses were summed to create a composite score ranging from 0 to 8, with a higher score indicating a higher level of food insecurity. For analytic purposes, scores of 0-3 were categorized as 'low food insecurity,' scores of 4-6 as 'moderate food insecurity,' and scores of 7-8 as 'high food insecurity.' These cut points align with those described in a previous study.[50] The FIES is a validated tool developed by the United Nations Food and Agriculture Organization; it is based on the United States Department of Agriculture's food insecurity screener and is currently used by 146 countries to assess food insecurity status among households.[51]

Control Variables

Control variables included the sociodemographic variables sex (0=male, 1=female), age (continuous), race/ethnicity (responses were open-ended and then categorized as 0=White, 1=Black, 2=Hispanic, 3=Asian/Native Hawaiian/other Pacific Islander [ANHOPI], 4=Middle Eastern/Armenian, 5=other/mixed race), primary language family speaks at home (0=not English, 1=English or English+other language), and nativity status (0=not USA born, 1=USA

born). Other control variables included personal financial situation (1=less than peers, 2=same as peers, 3=more than peers), general health status (0= terrible/poor/average, 1=good/excellent), and accurate knowledge of daily recommended milligrams (mg) of sodium (0=inaccurate knowledge, 1=accurate knowledge). Questions corresponding to these variables were the same or adapted from previous DPH studies.[45–48]

Data Analyses

A conceptual framework guided study analyses (**Figure 1**). It was informed by existing research[42,43] and univariate, bivariate, correlation, and factor analyses. The variance inflation factor (VIF) for these variables was examined to mitigate potential multicollinearity. A VIF cutoff value of above 10 typically indicates the presence of multicollinearity.[52] In the study, the VIF was less than 2, indicating a negligible presence of this issue among the variables. The final analytic sample (n=3,133) excluded sparse data, outliers, and missing responses for the selected variables. The sequence of analyses was organized around three study parts, as described below. All data were analyzed using the statistical software STATA version 14.1 (StataCorp LLC, College Station, Texas).

Descriptive analyses

Frequencies and percentages were generated for all participant characteristics, food insecurity levels, and sodium-related dietary behaviors in the full sample.

Multivariable logistic regressions

Multivariable logistic regression (analyses) models were constructed to examine the associations between food insecurity and the four dietary behaviors of interest: 1) likelihood of ordering plant-centered meals; 2) consumes packaged foods; 3) adds salt when cooking/preparing foods; and 4) high frequency of eating processed foods high in salt. Adjusted odds ratios (AOR) and corresponding 95% confidence intervals (CIs) were generated for each of these models.

Moderation analysis

To assess the extent to which race/ethnicity influenced the associations between food insecurity and the four sodium-related dietary behaviors, a multi-degree of freedom test (omnibus test) was performed to test interactions between food insecurity and race/ethnicity for each of the sodium-related dietary behaviors. Corresponding test statistics and p-values were generated to identify statistically significant interactions (threshold: $p < .05$).

Results

Descriptive analyses

Table 1 shows the sociodemographics of the survey participants. Many were female (76.2%), Hispanic (46.9%), and had families that primarily spoke English or English with another language at home (54.1%). The mean age was about 23 years. Most were born in the U.S. (83.5%) and perceived their general health status as average/poor/terrible (66.7%). About 44.2% reported they had less money to spend than other individuals their age. Only 10.9% were able to accurately identify the recommended daily sodium consumption limit for an adult (i.e., < 2,300 mg). About a quarter (25.0%) had moderate or high levels of food insecurity. For the four sodium-related dietary behaviors (dependent variables), most reported they were very likely or

likely to order plant-centered meals (69.6%), avoid or limit consuming packaged foods (58.7%), often/always add salt when cooking or preparing foods (50.2%), and sometimes or rarely eat processed foods high in salt (61.6%).

Multivariable logistic regressions

Results from the multivariable logistic regression models are presented in **Table 2**. Compared to participants who had low food insecurity (food secure), participants with high food insecurity had higher odds of reporting 'likely to order' plant-centered meals (AOR = 1.55, 95% CI = 1.16-2.05). Those with moderate food insecurity, as compared to those with low food insecurity, had higher odds of frequently eating processed foods high in salt (AOR = 1.40, 95% CI = 1.13-1.74).

Moderation by race/ethnicity

In the moderation analysis, race/ethnicity did not significantly moderate the associations between food insecurity and the four dietary behaviors of interest (data not shown).

Discussion

To the best of our knowledge, this study is among the first to describe the potential connections between food insecurity and four sodium-related dietary behaviors that can protect or increase university students' risk of developing hypertension and diet-related cardiovascular disease later in life. Although data collection was completed between 2018 and 2019, our findings remain relevant to this day, as both food insecurity and poor diet quality in this defined population have increased during the post-pandemic recovery period. Presently, there is no consensus or post-crisis data to guide health interventions that can address these growing public health issues. For

university researchers, program implementers, and student health clinicians alike, there may be value in spotlighting these gaps or areas for improvement in student health and health promotion, even as the world strive to return to pre-COVID-19 normalcy. Framing messaging from a physical and planetary health perspective, for example, could be one approach to reaching this younger population. Promoting consumption of low-sodium plant-centered meals not only encourage healthier and lower sodium intake, but it also protects the planet indirectly.[53] In real-world practice, these types of strategies are frequently overlooked as viable options for addressing health. In the present study, we discuss several notable findings within this context.

First, students that experience high food insecurity had higher odds of ordering more plant-centered meals, as compared to peers who had low food insecurity. This finding did not support our hypothesis that food insecurity would be associated with lower ordering of plant-centered meals. In prior studies, food insecurity has been found to be inversely related to fresh fruit and vegetable intake.[54–56] However, many of these studies were conducted among general populations of adults and/or children in the U.S.[54,56] or outside of it,[55] and not exclusively among university students as a target population.

Second, students that experience moderate food insecurity, as compared to students who experience low food insecurity, had higher odds of frequently eating processed foods that are (typically) higher in salt/sodium. This finding partially supports our hypothesis that food insecurity would be associated with higher frequency of eating processed foods. The other (null) finding, high food insecurity was not associated with frequently eating processed foods, however, was somewhat surprising. Yet, not entirely unfounded, as there is evidence showing that adults and children with severe food insecurity generally have a significantly higher mean percentage of energy intake from ultra-processed foods than their more food secure

409 counterparts.[57] In the present study, it is plausible that highly food insecure students who order
410 plant-centered meals chose plant-centered options that were still highly processed and high in
411 salt/sodium because they are cheaper than fresh produce.

412 A work project at the NOVA School of Business and Economics found that plant
413 alternatives to foods like meat options were often higher in sodium than the meat options they
414 were meant to replace.[13] Emerging research also suggests that a potential consequence of
415 transitioning from an animal- to a plant-based diet is increased sodium intake.[58] Moreover, some
416 studies have unveiled similar counterintuitive results: vegetarians frequently consume more
417 salt/sodium than non-vegetarians,[59] plant-based diets can be unhealthy and may even increase
418 chronic disease risk,[60] and not all plant-based diets are equal.[61]

419 In general, plant-centered meals that are available on university campuses may be high in
420 sodium, marketed with processed foods, and/or priced differently depending on the type of venue
421 selling them, the location of the venue, and/or the season in which they are sold. It is also
422 possible that university students with high food insecurity are cost conscious, leading them to
423 consume lower nutritional quality plant-centered options that are less expensive. This latter
424 possibility is supported by recent data highlighting how processed foods are becoming more
425 economical than healthy alternatives for many groups, including students.[62,63] More research is
426 clearly needed to disentangle why moderate food insecurity is associated with increased odds of
427 frequently eating processed foods while high food insecurity is associated with higher likelihood
428 of ordering more plant-centered meals.

429 Third, race/ethnicity did not significantly moderate the associations found between food
430 insecurity and the four sodium-related dietary behaviors (study outcomes). This finding is
431 contrary to our study hypothesis, indicating that, at least for salt/sodium consumption,

race/ethnicity made no difference. While more research is needed to better understand this absence of significant moderating effects, a plausible explanation could be that engaging in desirable sodium-related dietary behaviors is much more challenging to achieve than originally thought and is universal among all Americans alike, posing a steep challenge not only for university students but also for low-income households and communities of color. Emerging data supports this interpretation—a high percentage of U.S. adults fail to adhere consistently to recommended daily sodium intake levels. A study using NHANES data, for instance, found that, between 1999 and 2016, African Americans, Caucasians, and Hispanics all consumed about 3,278 to 3,027 milligrams of sodium per day.[64] These high sodium consumption trends were attributed to these groups' non-adherence to sodium standards/recommendations, principally as a result of limited individual knowledge about sodium's harmful effects and/or a lack of broader support for sodium reduction in the food system.[65–67]

Limitations

As with survey studies of this kind, our investigation is subject to several limitations. First, it is not possible to draw causal inferences about relationships between food insecurity and the four sodium-related dietary behaviors given that the survey data are cross-sectional. As a result, findings should be interpreted carefully without overreaching. Second, there are alternative ways to code many of the variables included in the multivariable logistic regression models. For example, the expressed accuracy of the recommended milligrams (mg) of sodium per day for the sodium knowledge variable was based on a general cut-off of less than 2,300 mg/day. This cut-off, however, could also be defined using a tiered framework, given that the 2020-2025 Dietary Guidelines for Americans recommends sodium consumption levels based on

455 the absence or presence of chronic conditions. That is, the tiered levels could be: (i) consumption
456 of less than 2,300 mg of sodium daily *only* for individuals over the age of two years who are
457 *without* hypertension, chronic kidney disease, diabetes, or other specific disease risk factors[10]; or
458 (ii) consumption of no more than 1,500 mg of sodium daily for those with these conditions.
459 Third, some of the study variables were based on internally developed questions that were not
460 worded optimally, likely influencing the way participants interpreted or responded to them.
461 Albeit, during their development, efforts were made to minimize potential bias by iteratively
462 refining the questions' wording and obtaining feedback from trained nutritionists and nutrition
463 researchers. The questionnaire was also pretested with university students prior to field
464 implementation. Nevertheless, for future surveys, many of these questions could and should be
465 reworded to improve their quality and comprehension. Fourth, while exercise and sedentary
466 behaviors can greatly impact cardiovascular health,[68] this area of research and health promotion
467 was outside the scope of our study due to the funder's emphasis on sodium reduction and
468 nutrition-based interventions—our funder's focus was on diet quality as it relates to sodium
469 consumption. This lack of funding support limited the study's ability to fully assess
470 exercise/sedentary lifestyles among the survey participants. If we had been able to collect these
471 data, we could have generated further insights regarding the contributions of exercise and
472 sedentary behaviors to student health. Fifth, the data collected from the three universities were
473 gathered via a web-based format and analyzed without accounting for campus or school
474 differences; these differences by institutional location could have influenced the way students
475 responded to the questions. Sixth, the data were collected during 2018-2019, before the COVID-
476 19 pandemic, which may have introduced temporal validity bias to study analyses. Finally, there
477 may have been self-reported and social desirability biases that affected the way students

interpreted and responded to the survey. Many students may have answered the questions based on what they thought was correct/socially acceptable rather than expressed their true feelings or opinions about these topics.

Despite these limitations, the present study also had notable strengths, such as capturing data on a student population with diverse sociodemographic characteristics uniquely representative of the era prior to and during the COVID-19 pandemic. It also explores the associations between food insecurity and the consumption of plant-centered meals, a novel research topic that has become even more important given the growing burden of food insecurity and climate change.[69] For example, a recent review of various studies found that food insecurity had increased from about 10% among all U.S. households before the COVID-19 pandemic to about 25-30% during the pandemic,[70] levels which appear to have remained more pronounced among university students similar to our study sample. Specifically, the California Student Aid Commission's 2023 Food and Housing Survey (which includes the three California State University schools in the 2018-19 CSU Sodium Reduction Initiative Survey) found that over two-thirds of CSU students (66%) were food insecure during the 2022-2023 academic school year, a nearly 70% increase from 2018-19 (**Figure 2**).[71] If a comparable and expected rise is assumed for the same timeframe, about 42% of the students in the CSU Sodium Reduction Initiative Survey would have reported being food insecure in 2023.

Conclusions

While not yet widespread, diets centered around plant-based foods, such as vegan and vegetarian diets, are gaining traction among Americans, including young adults.[72] Meanwhile, meat consumption in the U.S. is slowing or showing signs of decline.[73] Taken together, these two

501 divergent trends indicate an opportunity for health interventions to promote plant-based or plant-
502 centered diets as an alternative way to strategically promote health, beyond the typical promotion
503 of fruit and vegetable consumption alone. Achieving sodium reduction and better health through
504 this approach, however, may require further investments in research, program development, and
505 business/expert know-hows, especially given the paucity of real-world interventions that are
506 currently ready to scale and promote sodium reduction in this way.

507 The present study adds to gaps in the literature by providing rich insights and empiric
508 evidence in support of implementing more plant-centered meal/food interventions in universities.
509 In most U.S. state universities, campus life can have enormous influence on students' lifestyle
510 and decision-making. Thus, they could and should be leveraged to improve student health by
511 offering more plant-centered meals or food options that are low in salt/sodium via on-campus
512 food pantries, dining halls, restaurants, and vending machines. To reduce students'
513 cardiovascular risk, increasing access to *affordable*, low-sodium plant-centered options will be
514 key. This prospective goal could be achieved in a variety of ways, ranging from implementation
515 of healthy nutrition standards for on-campus food venues (e.g., cafeterias/restaurants, vending
516 machines, etc.) to increasing access to free/low-cost food closets which stock fresh plant-based
517 foods (e.g., fruits, vegetables, etc.). In tandem, on- and off-campus promotional campaigns
518 should be undertaken to help educate students about sodium reduction and the benefits of
519 choosing plant-based foods, not only for the primary prevention of cardiovascular disease later in
520 life, but also for the preservation of planetary health. Collectively, these mutually reinforcing
521 interventions could create the desirable university conditions required to drive students toward
522 healthier food selection/consumption and to provide them with the skills and resources they need
523 to achieve optimal health, presently and throughout the course of their lifetime.

Acknowledgements: The authors thank Michelle Wood, Allison Kwan, Mariana Reyes, and Ranjana Wickramasekaran from the Los Angeles County Sodium Reduction Initiative for their assistance in developing the survey instrument, from which the present study is based on. The authors also thank the students and research assistants at the California State University, Northridge's Marilyn Magaram Center for their assistance with disseminating the survey.

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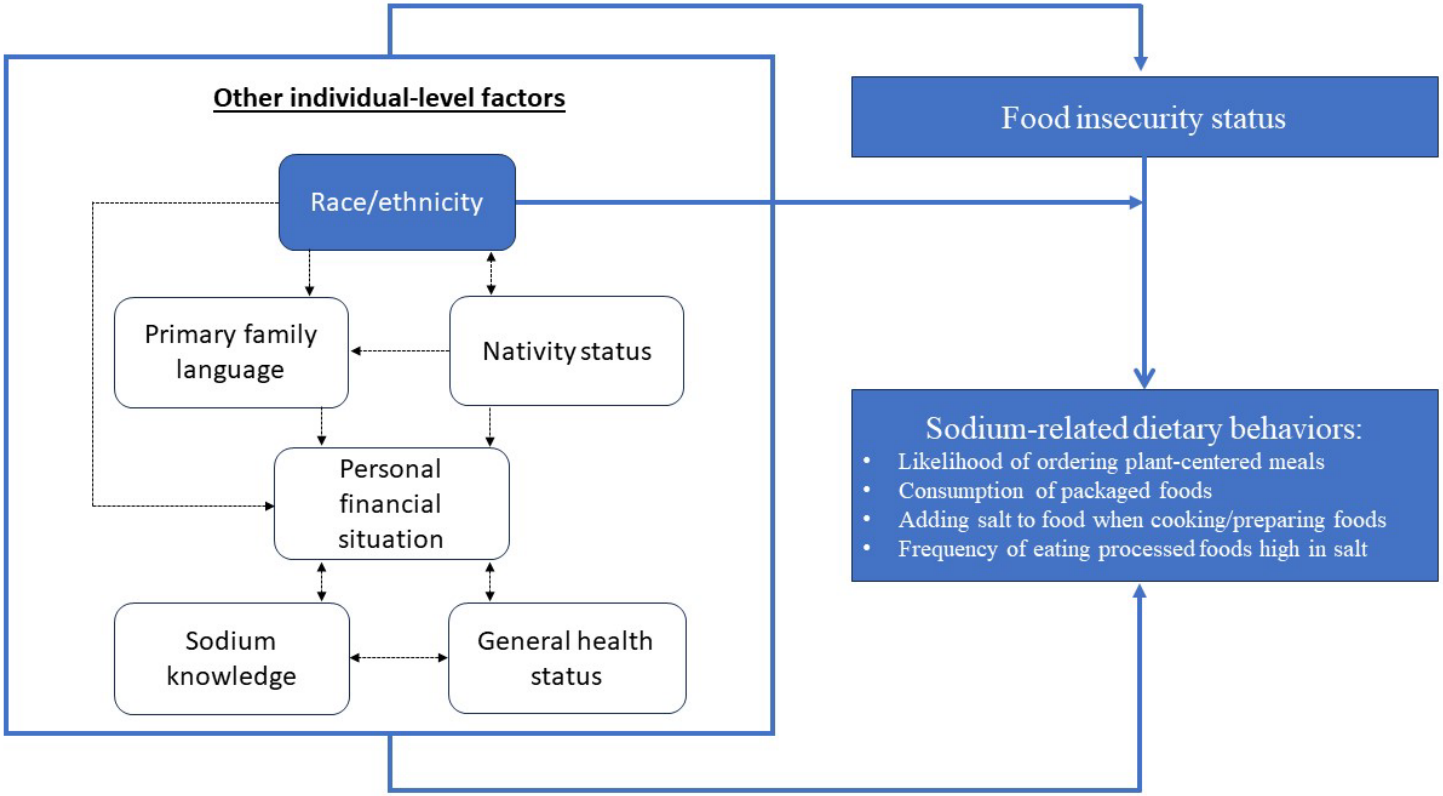


Figure 1. Conceptual framework used to guide study analyses of a web-based survey of three California State University schools, Academic Year 2018-2019.

This framework posits that the associations between food insecurity and sodium-related dietary behaviors are moderated by race/ethnicity, controlling for other individual-level factors. Solid blue lines depict the relationships examined in the present study. Dotted black lines depict potential relationships between other individual-level factors that were not examined in the present study.

Table 1. Characteristics, food insecurity levels, and sodium-related dietary behaviors among student participants of the 2018-2019 California State University Sodium Reduction Initiative Survey.

	n (%)[†] or mean [SD]
	3,133 (100)
Characteristics	
Sex	
Female	2,388 (76.2)
Male	745 (23.8)
Age	23.3 [5.6]
Race/ethnicity	
White	467 (14.9)
Black	116 (3.7)
Hispanic	1,468 (46.9)
ANHOPI[‡]	763 (24.4)
Middle Eastern / Armenian	142 (4.5)
Other/mixed	177 (5.7)
Family language spoken at home	
Non-English	1,439 (45.9)
English or English and other language	1,694 (54.1)
Nativity status	
Not born in the USA	516 (16.5)
Born in the USA	2,617 (83.5)
Personal financial situation	
Less than peers	1,384 (44.2)
Same amount as peers	979 (31.3)
More than peers	770 (24.6)
Perceived general health status	
Average/Poor/Terrible	2,088 (66.7)
Excellent/Good	1,045 (33.4)
Accuracy of reporting mg of sodium	
Inaccurate knowledge	2,793 (89.2)
Accurate knowledge	340 (10.9)
Food insecurity	
Food insecurity levels	
Low	2,353 (75.1)
Moderate	462 (14.8)
High	318 (10.2)
Sodium-related behaviors	
Likelihood of ordering plant-centered meals	
Not likely	954 (30.5)
Most likely	2,179 (69.6)
Typically limits consuming packaged foods	
Does not limit packaged foods	1,295 (41.3)
Limits packaged foods	1,838 (58.7)

Frequency of adding salt when cooking/preparing foods	
Adds frequently	1,572 (50.2)
Does not add frequently	1,561 (49.8)
Frequency of eating processed foods high in salt	
Eats frequently	1,203 (38.4)
Does not eats frequently	1,930 (61.6)

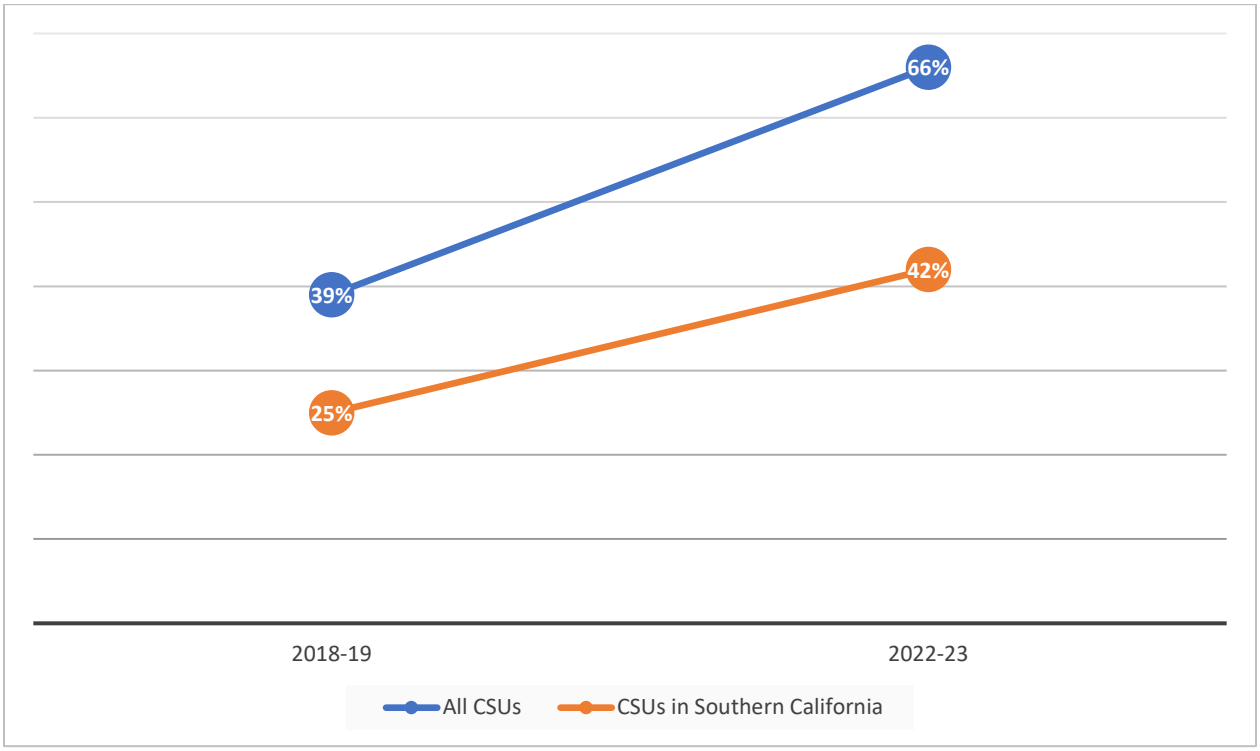
† Percentages may not add up to 100% due to rounding;
‡ANHOPI, Asian, Native Hawaiian or Other Pacific Islander.

Table 2. Multivariable logistic regression analyses describing the associations between food insecurity and four sodium-related dietary behaviors among students from three California State University schools, Academic Year 2018-2019 (n=3,133).

	Behavior 1	**Behavior 2**	**Behavior 3**	**Behavior 4**
	Likely to order plant-centered meals AOR† (95% CI)	Consumes packaged foods AOR† (95% CI)	Adds salt when cooking/preparing foods AOR† (95% CI)	High frequency of eating processed foods high in salt AOR† (95% CI)
Independent Variable				
Food insecurity (ref=low food insecurity)				
Moderate food insecurity	1.24 (0.98-1.57)	1.18 (0.95-1.46)	1.17 (0.95-1.45)	1.40 (1.13-1.74)**
High food insecurity	1.55 (1.16-2.05)**	1.01 (0.79-1.30)	1.00 (0.78-1.28)	1.01 (0.78-1.30)
Covariates				
Sex (ref=male)				
Female	2.24 (1.87-2.67)***	0.83 (0.70-0.99)*	1.34 (1.13-1.59)**	1.20 (1.01-1.44)*
Age	1.04 (1.02-1.06)***	0.97 (0.96-0.99)***	1.00 (0.98-1.01)	0.98 (0.96-0.99)**
Race/ethnicity (ref=White)				
Black	0.77 (0.49-1.21)	1.03 (0.67-1.57)	1.33 (0.89-2.01)	0.87 (0.56-1.34)
Hispanic	0.97 (0.75-1.26)	0.78 (0.62-1.00)*	0.99 (0.78-1.25)	0.95 (0.74-1.21)
ANHOPI‡	0.68 (0.52-0.90)**	1.21 (0.93-1.56)	1.40 (1.09-1.80)**	0.94 (0.72-1.23)
Middle Eastern / Armenian	0.70 (0.45-1.08)	1.17 (0.77-1.76)	1.75 (1.17-2.62)**	1.28 (0.84-1.95)
Other/mixed	1.11 (0.75-1.66)	0.99 (0.69-1.41)	1.33 (0.94-1.88)	1.25 (0.87-1.79)
Family language at home (ref=non-English)				
English / English and other	0.69 (0.57-0.83)***	1.25 (1.05-1.48)*	0.93 (0.79-1.11)	1.13 (0.95-1.35)
Nativity status (ref = Not USA born)				
Born in the USA	0.87 (0.69-1.10)	1.37 (1.10-1.71)**	0.77 (0.62-0.94)*	1.54 (1.23-1.93)***
Personal financial situation (ref = more than peers)				
Less than peers	0.83 (0.68-1.03)	1.05 (0.86-1.28)	1.21 (0.99-1.46)	0.98 (0.80-1.19)
Same amount as peers	0.98 (0.79-1.21)	1.07 (0.88-1.30)	1.02 (0.84-1.23)	0.81 (0.66-0.99)*
Perceived general health status (ref=Average/poor/terrible)				
Excellent/good	1.28 (1.07-1.52)**	0.54 (0.46-0.63)***	0.80 (0.68-0.93)**	0.47 (0.40-0.56)***
Accuracy reporting mg of sodium (ref=Unacceptable range)				
Acceptable range	1.95 (1.46-2.59)***	0.74 (0.58-0.94)*	0.92 (0.73-1.16)	0.78 (0.61-1.00)*

†AOR = Adjusted Odds Ratio; ‡ANHOPI, Asian, Native Hawaiian or Other Pacific Islander; *$p < .05$. **$p < .01$. ***$p < .001$.

Figure 2. Increase in the number of students who are food insecure at all California State University schools from 2018-19 to 2022-23[a], compared with a projected increase at three large California State University schools in Southern California for the same timeframe.[b]



[a] Data source: California Student Aid Commission. The 2022-23 data (n=23,687) were obtained from the 2023 Food and Housing Survey, a supplement to the triannual Student Expenses and Resources Survey (SEARS). The most recent rounds of SEARS was in 2018-19 and 2021-22. Nearly half of the student participants in the 2022-23 survey were Hispanic (48%), nearly two-third (65%) were female, and 62% to 73% were experiencing basic needs (housing, food) insecurity arising from personal financial situation. Eighteen California State University schools (All CSUs, n=4,728), including the three schools in the CSU Sodium Reduction Initiative Survey, were included in the 2022-23 Food and Housing Survey. https://www.csac.ca.gov/food-and-housing-survey

[b] Data source: The Los Angeles County Department of Public Health and the California State University (CSU) system in Southern California. The 2018-19 data (n=3,133) were obtained from the CSU Sodium Reduction Initiative Survey conducted at three large CSU schools. Nearly half of the student participants in this survey were Hispanic (47%), over two-third (76%) were female, and about 75% indicated their personal financial situation
were the same or less than that of their peers.

Note: Although both data sources utilized the U.S. Department of Agriculture's (USDA's) food insecurity measure to determine who was 'food insecure', the 2023 Food and Housing Survey and the SEARS used the USDA Six-Item Short Form while the CSU Sodium Reduction Initiative Survey used the Food Insecurity Experience Scale. The 2022-23 data point for the three CSUs in Southern California were estimated based on the rate of change for all CSUs in the 2023 Food and Housing Survey.