THE PENNSYLVANIA STATE UNIVERSITY
SCHREYER HONORS COLLEGE

DEPARTMENT OF NUTRITIONAL SCIENCES

Food Insecurity As A Longitudinal Predictor of Diet, Sleep, Mental Health and College Academics

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SPRING 2022

A thesis
submitted in partial fulfillment
of the requirements
for baccalaureate degrees
in Nutritional Sciences and Letters, Arts and Sciences (Linguistics)
with honors in Nutritional Sciences

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ABSTRACT

Background: Food insecurity (FI) and its negative relationship with GPA has been thoroughly studied cross-sectionally in college students, but few have considered how FI changes over the course of a semester. Further, many previous studies have used the 6-item USDA short form, which is believed to overestimate food insecurity prevalence in this population. None of the other outcomes, besides academic performance measured via GPA alone, have been analyzed by food security status in college students over time.

Aims: This study sought to assess the FI prevalence for 2nd and 3rd year undergraduate students at Penn State's University Park campus and how that prevalence changed over a semester. It also sought to analyze associations between FI status and diet, sleep, mental health and academic outcomes.

Methods: Participants (n=79 for phase 1, n=77 for phase 2) completed two surveys, one in October and another in December to reflect on the previous month during Fall 2021. FI was assessed using the 10-item Adult Food Security Survey Module. Diet, sleep, mental health and academic outcomes were assessed via validated questionnaires. Descriptive statistics were used to report food insecurity prevalence and participant demographics. Within-person differences from phase 1 to phase 2 were also analyzed. An unadjusted analysis revealed whether baseline food security status could predict any of the outcomes of interest. Afterwards an adjusted analysis was performed, controlling for potentially confounding variables identified in previous literature, including gender, race, first generation student status, BMI and family financial support.

Results: Participants were primarily white (71.8%), non-Hispanic (96.1%) American young adult women (77.2%). FI prevalence was 26.6% at phase 1 and fell to 22.1% at

phase 2, although only 1 participant changed status. An adjusted regression model showed that FI participants were more likely to consume ½ cup fewer fruits and vegetables, to have worse overall sleep quality, to have worse stress, depression and anxiety symptoms, and to have worse attention span in class. FI was not associated with self-report or university-report GPA, frequency of missing class or self-report ability to understand class material. In all cases, baseline food insecurity status did not predict outcome changes from phase 1 to phase 2.

Conclusion: FI prevalence did not change significantly between phases, but this may be attributable to the timing of Fall break. FI was not significantly predictive of a change in GPA, potentially indicating GPA is not a sensitive enough predictor for change over one semester. Despite our sample being at decreased risk for FI and our use of the 10-item USDA Adult Food Security Survey Module, FI prevalence was still higher than the national household average and within the previously identified range of food insecurity prevalence seen in college students. Additionally, further research is needed to determine why FI students have lower GPAs on average, since there was no difference in missing class or self-reported ability to keep up with material.

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ACKNOWLEDGEMENTS

To Muzi, for igniting a passion for nutrition I will carry forever.

To Allison, for listening to my crazy IUG program ideas.

To both, for their immense kindness when everything was collapsing.

To Nan and Dr. Savage-Williams, for their flexibility when deadlines were closing in.

To Abriana, for lending me a desk when I had none.

To Leigh, who used all the patience in the world to teach me how to code.

To my husband, who made supporting me a career, with only a promise to the future.

And to my mum, who dictated her own life to give me opportunities I won't waste.

Thank you.

CHAPTER ONE

Introduction

Food insecurity is defined as inadequate access to safe and nutritious foods in sufficient amounts for healthy growth and activity (Coleman-Jensen et al., 2021). Although it is often conceptualized as hunger and reduced food intake, this actually only describes the most severe form. Having difficulty affording healthy food, or accessing stores selling healthy food, are also considered food insecurity. It is typically measured using one of the United States Department of Agriculture (USDA)'s Food Security Survey Modules. Based on the USDA's definition, there are 4 levels of food security: food secure, marginally food secure, food insecure and severely food insecure.

According to the USDA, about 10.5% of US households experienced food insecurity during 2020 (Coleman-Jensen et al., 2021). Current research suggests that food insecurity rates in college students are higher than in the general population (Nikolaus et al., 2020). A recent meta-analysis summarizing 51 (49 cross-sectional) studies on college students in the US estimated an average food insecurity prevalence of 41.0%, despite a wide range of individual study rates, from 10% to 75% (Nikolaus et al., 2020).

College students are a unique group, facing multiple economic hardships like high tuition, housing, and utility costs, while generally being unable to work full-time jobs and living independently for the first time. As more non-traditional students attend higher education, many of them cannot rely on their families for financial support, and research suggests that scholarships and grants are not keeping up (el Zein et al., 2019; Gaines et

al., 2014). The heterogeneity of different universities may also influence their food insecurity prevalence, e.g. how rural or urban they are, whether students majorly live on or off campus, and the accessibility of affordable grocery stores (el Zein et al., 2019). Meanwhile, studies are more likely to report higher food insecurity prevalence if they use a shorter reference period length or if the use a shorter version of the USDA Household Food Security Survey Module, especially the 6-item form (Nikolaus et al., 2020). Shorter reference periods with follow up throughout the year may more accurately reflect a student's experience, since their food security status may be different while at home living with family, during the Fall semester or during the Spring semester.

Predominately studies in this area have been cross-sectional in nature, although the few longitudinal ones suggest that prevalence and severity increase as the semester progresses (Bruening et al., 2018; van Woerden, Hruschka, & Bruening, 2019).

Besides the immediate concern of hunger for food insecure students, there is also ample research suggesting this group tends to struggle academically compared to their food secure peers, including lower semester and cumulative GPAs, being more likely to drop a course, and to drop out of school entirely (van Woerden, Hruschka, & Bruening, 2019; Weaver et al., 2020). These relationships have remained statistically significant even after controlling for other predictors of academic success, including high school success (van Woerden, Hruschka, & Bruening, 2019), gender, race/ethnicity, parent education, and socioeconomic status (Nikolaus et al., 2020). The present study seeks to enlighten the relationship between food insecurity and academic outcomes by suggesting four potential related outcomes discussed across the literature: diet quality, sleep quality,

mental health, including depression, anxiety, and perceived stress, and academic performance.

Diet

As already mentioned, college represents a major shift into independence for most students, which includes the ability and need to choose and prepare their own food (Dhillon et al., 2019). It is well known that college students frequently have unhealthy dietary patterns, including low intakes of whole grains and vegetables with higher intakes of added sugars (Leung et al., 2019). However, food insecure students consume the lowest amounts of whole grains, vegetables, and dairy and the highest amounts of added sugar when compared to their food secure peers (Dhillon et al., 2019; Leung et al., 2019). Young adulthood is a critical transition period for dietary patterns, with those developed during this age majorly continuing into adulthood. Hence a similar pattern has been found in a systematic review of US adult diets, wherein the food insecure were more likely to have lower Healthy Eating Index scores and to fail to meet recommendations for fruit, vegetables and dairy (Hanson & Connor, 2014).

Although food insecure individuals tend towards high energy, hyperpalatable foods, studies are conflicted about the relationship between BMI and food insecurity (Hanson & Connor, 2014). This is considered the “Food Insecurity-Obesity Paradox,” which notes that although food insecurity is typically related to hunger and starvation, many individuals experiencing it have overweight/obesity (Dhurandhar, 2016). One potential explanation considers that individuals with severe food insecurity are more

likely to experience hunger, tend to have lower than average BMI, while individuals with moderate food insecurity who can afford some, mostly unhealthy, food tend to have higher BMIs. Since these groups are frequently pooled for comparison against the food secure, the two ends average out.

Qualitative research in college students suggests the number one factor in food choice is price, with healthy foods having a perceived higher cost; the next biggest factors are food familiarity and appeal, followed by time required to acquire or prepare (Dhillon et al., 2019). Food insecure college students in particular are more likely to have lower cooking and food agency scores and overall less self-efficacy, in part because they are less likely to have access to cooking facilities (Leung et al., 2019). Further, students have reported caring less about healthy eating during times of stress, such as finals week (Dhillon et al., 2019). This correlates with an expected increase of food insecurity prevalence at the end of the semester, potentially due to running out of loan or financial aid money (Bruening et al., 2018). The increased prevalence does not seem to persist to the start of the next semester, suggesting that many college students experience food insecurity intensely but acutely (Bruening et al., 2018).

Notably, even students who are on meal plans report higher rates of food insecurity as the semester progresses, despite having leftover (or unlimited) meal swipes (van Woerden, Hruschka, Vega-López, et al., 2019). For these students, it is possible time scarcity and food accessibility is a more important aspect of food insecurity than affordability (van Woerden, Hruschka, Vega-López, et al., 2019). Students using meal swipes are an excellent comparison tool because all students have access to the same food, and yet, food insecure students still consume less healthy foods and more unhealthy

ones compared to their food secure peers (Mei et al., 2021). Some potential explanations for this are that students reporting as food insecure come from food insecure backgrounds and are acting out learned habits, or that they may have increased stress and mental load causing them to choose less healthy options (Mei et al., 2021).

Sleep

Approximately only one third of US adults meet CDC recommendations for hours of sleep a night, and this number is even lower in college students (Becerra et al., 2020). A systematic review and meta-analysis of 8 studies on sleep suggests that food insecurity correlates to poorer sleep outcomes, rated using the Pittsburgh Sleep Quality Index (PSQI) (Arenas et al., 2019). Many studies use participant reported sleep to indicate overall sleep duration, sleep disturbances (waking up for any reason, snoring, etc), sleep latency (tired or sluggishness right after waking up) and daytime sleepiness using the PSQI. For example, data from the National Health and Nutrition Examination Survey (NHANES) suggests that food insecure, non-pregnant women were more likely to report shorter sleep on average, whereas men were more likely to report greater sleep latency (Ding et al., 2015). One author's manuscript considered food insecurity relative to objectively measured sleep using a wrist device to record bed, sleep, wake and rise times (Troxel et al., 2020). They found that food insecurity was associated with significantly worse sleep disturbances and both very short and very long sleep duration (Troxel et al., 2020). Very long sleep duration can be considered negative for health because it is most frequently an attempt to make up for lost sleep while further disrupting sleep patterns.

Food insecure students have reported overall shorter sleep durations, with higher rates of sleep apnea and/or snoring in students who report skipping meals (Becerra et al., 2020). Feeling tired during the day was correlated with feeling like one was unable to afford balanced meals, which may result from poor glycemic control related to poor diet (Becerra et al., 2020). There are many hormonal mechanisms relating insufficient food intake to poor sleep quality. For example, orexins are a type of neuropeptide that respond to low energy intakes by acting on the brain to increase wakefulness and metabolism to prepare a hungry person to search for food (Yamanaka et al., 2003). Another example may result from short sleep durations lowering leptin levels in the body; since leptin is meant to diminish feelings of hunger, the opposite occurs (Leproult & van Cauter, 2009). This might occur to make up for the higher energy needs associated with staying awake longer, but the hunger might itself make it difficult to sleep. Overtime, these responses may become maladaptive and disrupt sleep to the point of insomnia-like symptoms.

Consequently, food insecure students report more daytime consequences like falling asleep during class (Becerra et al., 2020). Despite all of this, students seem unable to report the overall quality of their sleep; in one study, over 70 percent of participants rated their sleep as very good, while over 50 percent of participants from the same study admitted to difficulty staying awake while driving, eating and engaging in social activities (Orzech et al., 2011).

Mental Health

Finally, another strong association exists between food insecurity and overall poor mental health, described here as depression, anxiety and perceived stress. One systematic review and meta-analysis of food insecure US adults found 57 studies in depression and 13 in anxiety and stress which were often combined together (Arenas et al., 2019). They found a consistent increased risk for both depression and anxiety/stress even after controlling for differences in types of scales or questionnaires used to assess these symptoms (Arenas et al., 2019). While college students already face overall higher rates of adverse mental health than the general population, studies report that food insecurity still has an additional significant impact, for depression (Bruening et al., 2016; Raskind et al., 2019; Wattick et al., 2018), anxiety (el Zein et al., 2019; Wattick et al., 2018), and stress. One qualitative study sought to assess why food insecure students, defined as those who accessed food resources at least once in the previous year, had worse mental health (Meza et al., 2019). Students reported difficulty forming social relationships because of feeling left out of social gatherings around food, resentment of others in stable situations who could afford to eat what they want, and shame (Meza et al., 2019).

Recent research has considered the impact of the COVID-19 pandemic on food insecurity and mental health. One study in US adults found that food insecurity increased overall feelings of depression, anxiety and stress, and specifically increased stress about the COVID-19 pandemic (e.g. health, income, etc.) (Wolfson et al., 2021). While many students returned to live with their families, many did not and both groups faced high rates of unemployment (Davitt et al., 2021). As a blanket rule, all students experienced

worse depression-like symptoms during the Pennsylvania stay-at-home order (Coughenour et al., 2021) and worse anxiety/stress while attending school virtually through Zoom (Wang et al., 2020). However, students who moved back home were less likely to report food insecurity, binge drinking to cope, or panic buying, most likely representing the beneficial nature of support from home (Davitt et al., 2021).

Academic Performance

Although academic performance has been strongly associated with food insecurity status, few studies have suggested potential mechanisms to explain the association. One possibility is that the previously mentioned variables: diet quality, sleep quality and mental health, are associated with both food insecurity status and academic performance, and thus mediate the relationship between the two.

For example, a poor diet caused by food insecurity could impact academic performance. Hungry students might have increased difficulty paying attention in class, especially if they are preoccupied with thoughts or worries about food (Wattick et al., 2018). Similarly, they may have to devote more time to obtaining food and preparing or rationing it, taking time away from studying and homework (Weaver et al., 2020). In fact, food insecure students reported having lower expectations for their own academic performance and to rate their academic progress as worse when compared to similarly achieving students (Weaver et al., 2020).

It has also been considered that healthier diets generally may increase academic outcomes through better physical health and meeting recommendations for micro and

macronutrients. Students with a higher quality diet, defined as greater fruit or vegetable intake or as a high Healthy Eating Index score, correlated to higher average GPA (Ryan et al., 2021; Wald et al., 2014). Indeed, students who report eating out less frequently tend to have better GPAs (Reuter et al., 2020; Reuter & Forster, 2021). Importantly though, none of the studies comparing diet quality and GPA controlled for any kind of socioeconomic status; generally, individuals of higher status tend to consume higher quality diets (Hanson & Connor, 2014) and to have higher GPAs (el Zein et al., 2019).

Further, students report sleep as the second greatest contributor to their academic success, after stress (Orzech et al., 2011). Compared to non-student adults, college students have to deal with variable schedules every day because of classes and tend to have greater differences in bed and wake times during the week and weekend, contributing to longer sleep latency and overall shorter sleep duration (Orzech et al., 2011). Sleep regularity, independent of and in spite of sleep duration, has been correlated to lower GPA, suggesting regularly scheduled sleep, even at the expense of sleep length, is more beneficial (Phillips et al., 2017). In many studies, students who reported feeling tired during the day were significantly more likely to report lower cumulative GPA (Becerra et al., 2020; Nyer et al., 2013; Taylor et al., 2013). In another, students who reported experiencing sleep disturbances experienced greater deficits in cognitive function than those with shortened sleep duration, including greater difficulty recalling information over the past month (Nyer et al., 2013; Orzech et al., 2011). Tiredness might also result in lowered motivation for cognitive tasks (Gaultney, 2016). One study found that for each additional day per week a student experiences significant sleep impediment, they have a 10 percent greater likelihood of dropping one of their courses (Hartmann &

Prichard, 2018). In fact, analysis of poor sleep symptoms and severity in college first-years may predict college retention rates later on (Gaultney, 2016).

In a similar vein, students who consider themselves "evening people," meaning they are most alert during the late afternoon to evening hours, experience the result of poor sleep on academic outcomes (Adan & Almirall, 1991). These students have increased difficulty falling asleep at night and more sleep latency in the morning. Evening students are more likely to have lower GPA and higher drop-out rates than morning ones (Singleton & Wolfson, 2009). Evening students have also been shown to put forth less effort, have lower self-efficacy and to procrastinate on cognitive tasks (Singleton & Wolfson, 2009), so some researchers have suggested that evening type students have worse self-control or time management (Taylor et al., 2013). However, this paper considers whether evening type people are more likely to be food insecure, which could further explain poor self-efficacy related to schoolwork. In this way, eveningness would serve as another linking factor between food insecurity and sleep.

On mental health, students who noted an increase in stress levels during the pandemic also noted that this stress made it more difficult to concentrate in class and to perform well (Wang et al., 2020). In the same qualitative analysis of students mentioned previously, food insecure students reported difficulty focusing on class and studying because they were worried about where their next meal would come from (Meza et al., 2019). These students mentioned constantly feeling focused on the right now rather than on the big picture of academics, especially course long projects, making them feel less motivated, more tired, and worse about themselves (Meza et al., 2019). In a study on coping during the pandemic, only about half of the participants reported being able to

cope with the increased stress, with some students resorting to negative coping methods like binge drinking and isolation (Wang et al., 2020). Depression alone has been linked to lower exam scores, grades, and failure to complete a course (Raskind et al., 2018). Generally, depression is linked with apathy and low self-esteem, whereas stress and anxiety are more correlated with difficulty paying attention and memory. In fact, one study found a curvilinear relationship between perceived stress and GPA, suggesting that too little stress can also indicate a lack of motivation (Taylor et al., 2013).

Aims and Hypotheses

The goal of this study was to address the lacking areas of research mentioned in the above sections. Specifically, we aimed to identify the prevalence of food insecurity at Penn State's University Park campus over the course of a semester and to compare the prevalence to the previously estimated US household average. Based on previous research, we hypothesized that the food insecurity prevalence would be between 10-75%, and that it would be higher than the US household average of 10.5%. Further, we expected food insecurity prevalence to increase as the semester continued. This research also sought to address the apparent relationship between food insecurity and diet, sleep, mental health and academic outcomes. We hypothesized that students facing food insecurity at phase 1 would be more likely to experience suboptimal diet, sleep duration and quality, and mental health at both phase 1 and phase 2.

CHAPTER TWO

Methods

We conducted a longitudinal study of undergraduate students at the Pennsylvania State University within a single semester. We collected self-report information on participant demographics, food insecurity status, diet quality, sleep quality, mental health, including stress, anxiety and depression, and academic outcomes, including GPA and some novel questions. We also recorded university-report GPA from participants who consented. Outcomes were compared to assess whether any significant changes occurred from phase 1 to phase 2. An unadjusted and adjusted analysis were performed to check for associations between food security status at phase 1 and outcomes of interest at phases 1 and 2. We also assessed whether food insecurity status was significantly associated with a change from phase 1 to phase 2 in the outcomes of interest.

Participants

Participants were recruited in many ways. Flyers were posted in public buildings on campus and general education course professors sent emails encouraging their students to participate. An email was also sent to a listserv from the Penn State CORE study, which included only those who indicated interest in participating in future research. Using a link or QR code, interested individuals were directed to an eligibility screening survey on REDCap. They had to be at least 18 years old and a full-time

undergraduate student (e.g. taking at least 12 credits) at the time of the study, Fall 2021. They also had to have been a full-time student for at least the two semesters previous, Fall 2020 and Spring 2021, to ensure no participants were first-years. Individuals were ineligible if they were graduating Fall 2021 or Spring 2022, if they were married or had dependents, if they could not read or write fluently in English, or if they had any diagnosed mental disabilities and/or disorders, including depression and anxiety.

After screening, informed consent was obtained online over Zoom using REDCap. Participants had to log in with their university IDs, to verify their identity. Optionally, participants could allow the researchers access to a university report of their GPA at the beginning and end of the Fall 2021 semester. Participants were paid $10 for completing the first survey and $25 for completing the second. This study was approved by the Pennsylvania State University Institutional Review Board.

Measures

Participants responded to an online survey twice during the Fall 2021 semester, once in the first week of November and again in the first week of December, reflecting on the previous month. Phase 1 was meant to reflect the first full month of the semester, September, but due to difficulty recruiting participants the study was delayed until October; phase 2 was reflecting on the last full month of the semester, November. Participants were only invited to complete the survey during phase 2 if they completed the survey at phase 1. All study data were collected and managed using REDCap

electronic data capture tools hosted at Penn State Health Milton S. Hershey Medical Center and Penn State College of Medicine (Harris et al., 2009).

The full survey can be found in the Appendix. Demographics were collected for use as covariates, including age, gender, race, ethnicity, first generation student status, veteran status, international student status and place of residence (on- or off-campus). Participant self-reported height and weight at phase 1 were used to calculate BMI. Participants also indicated whether they were a recipient of free/reduced school lunches in high school, as a potential assessment of past food insecurity status. These data are reported but were not used in the adjusted analysis because second-year participants may have received free meals due to COVID-19 policies at the end of their last high school year rather than for financial need. Among other financial data, such as whether the participant was a recipient of a scholarship, grant or governmental loan, participants were asked whether their family had provided financial support over the previous month.

Food insecurity was assessed using the 10-item USDA Adult Food Security Survey Module form. Participants were classified as "food insecure" if they affirmatively responded to at least 3 or more items and as "food secure" if they did not. This aligns with the USDA's four levels of food security, starting with food secure, marginally food insecure, food insecure and severely food insecure. Here, the bottom 3 categories are all considered food insecure and are pooled for analysis.

Dietary data was collected using the 26-item Dietary Screener Questionnaire from the National Health and Nutrition Examination Survey (NHANES) 2009-2010 because of its validation within this population (Thompson et al., 2017). Survey data was converted to average daily intakes using regression model scoring algorithms created by NHANES

(Thompson et al., 2017). Given time restrictions on analyzing the data (especially the cereal data), only dairy and the combined fruit and vegetable intakes are reported here.

The 19-item Pittsburgh Sleep Quality Index was the primary assessment for sleep quality (Buysse et al., 1989), although a survey error lead to participants not answering one of questions ("When have you usually gotten up in the morning?"). Therefore, morning get-up time was calculated using how long it took participants to fall asleep and how long they actually slept. If anything, this means the composite score for this section, Habitual Sleep Efficiency, was overestimated for all participants. Despite this, the estimated global PSQI score was still used to represent overall sleep quality.

Mental health measures included the 10-item Cohen Perceived Stress Scale (PSS) (Cohen et al., 1983), the 10-item Center for Epidemiological Studies Depression Scale (CES-D) (Lewinsohn et al., 1997), and 3 anxiety screeners targeting generalized, social and panic symptoms (Anxiety and Depression Association of America, 2022). The anxiety screeners were summed for a score out of 3. Categories were also reported for the PSS and CES-D. For the PSS, scores between 0-13 were "Low Stress," scores, between 14-26 were "Moderate Stress," and scores between 27-40 were "High Stress." For the CES-D, a score lower than 16 points out of 60 was considered not showing significant signs of depression or "Not Depressed," whereas 16 points or more was "Depressed." Unlike other assessments, the CES-D referred only to the previous 1 week.

Finally, all participants self-reported their cumulative GPA before and after the Fall 2021 semester. A total of 60 participants opted to allow the university to report their official GPA records as well. They were asked how frequently they missed classes they were required to attend on average (less than once a week, around once a week, around

twice a week, or more than twice a week). Participants were also asked to report their attention span during class and their ability understand the material (excellent, good, fair or poor). Further, they were asked to indicate reasons for poor attention span during class. Because we created these questions for this survey as a more holistic marker of academic outcomes, scoring was decided on distribution of scores. For missing class, participants were scored as missing class less than once a week or more than once a week. For both attention span during class and their ability to understand the material, excellent/good responses were pooled, as were fair/poor responses.

Statistical Analysis

Descriptive statistics were used to report food insecurity prevalence and participant demographics. Participants with missing food insecurity status data were removed from the analysis. Normality of distributions for continuous variables was assessed using the Shapiro-Wilk test. Relationships between covariates were assessed using the Mann-Whitney test for continuous variables and the Pearson Chi-Square test for categorical variables. A Fisher's Exact test was used for covariates that had a group with 5 participants or fewer. Within-person differences for continuous and normally distributed food security, diet, sleep, mental health and academic variables were analyzed using paired t-tests; all other variables were analyzed using Wilcoxon Signed Rank tests.

An unadjusted analysis was used to reveal whether baseline food security status could predict diet, sleep, mental health and academic outcomes at phase 1, phase 2, and the difference between those outcomes at phases 1 and 2. Afterwards an adjusted analysis

was performed, controlling for potentially confounding variables significantly associated with both food insecurity status and at least one of the outcomes of interest identified in previous literature: gender, race, first generation student status, BMI and family financial support. Ethnicity and age were not controlled for due to the homogeneity of this sample for those characteristics. Results are reported as 95% confidence intervals and odds ratios. All analyses were performed using Stata/SE 16.0 (Stata Corporation, College Station, TX). Statistical significance was determined at $P < 0.05$.

CHAPTER THREE

Results

Out of the 252 individuals who completed the screening survey, 125 were deemed eligible. A total of 110 participants completed the consent process and opted to take part in the study. Only 92 participants responded to the phase 1 survey, and 2 participants were lost to follow-up during phase 2. Because participants with incomplete responses to the food insecurity module were removed from our analyses, leftover were a total of 79 participants at phase 1 and 68 participants at phase 2.

As shown in Table 1, participants were primarily white, non-Hispanic women in their early 20s, with normal BMIs, living off-campus and receiving financial support from their families. Most participants were not first-generation students or international students, and none were veterans. Few participants received free or reduced school lunches in high school. Analysis revealed that none of the covariates were significantly different by food insecurity status.

Descriptive statistics for food insecurity, diet, sleep, mental health and academic outcomes are shown in Table 2, with phases 1 and 2 and within person change. Food insecurity prevalence at phase 1 was 26.6% and fell to 22.1% during phase 2, however there were no significant changes in food insecurity status over time. Only 1 participant changed status, from food secure to food insecure.

Table 1: Demographic characteristics for study participants at phase 1[1]

Variables	**Total n=79**	**Food Secure n=58**	**Food Insecure n=21**	**P-Value[2]**
Gender				0.896
Men	18 (22.8%)	13 (22%)	5 (24%)	
Women	61 (77.2%)	45 (78%)	16 (76%)	
Age, years	20.2 (0.8)	20.2 (0.8)	20.1 (0.8)	0.288
Ethnicity				0.164
Non-Hispanic	74 (96.1%)	56 (97%)	18 (86%)	
Hispanic	3 (3.9%)	1 (2%)	2 (10%)	
Race				0.541
White/Caucasian	56 (71.8%)	42 (72%)	14 (66%)	
Non-White/Caucasian	22 (28.2%)	15 (26%)	7 (33%)	
First-Generation Student Status				
Yes	10 (12.8%)	5 (9%)	5 (24%)	0.078
No	68 (87.2%)	52 (90%)	16 (76%)	
Place of Residence				0.619
On-campus	23 (29.1%)	16 (28%)	4 (19%)	
Off-campus	56 (70.9%)	42 (72%)	17 (81%)	
Recipient of Free/Reduced Lunch in High School				0.135
Yes	8 (10.1%)	4 (7%)	4 (19%)	
No	68 (86.1%)	51 (88%)	17 (81%)	
International student				0.731
Yes	5 (6.3%)	4 (7%)	1 (5%)	
No	74 (93.7%)	54 (93%)	20 (95%)	
Veteran				
No	79 (100.0%)	58 (100%	21 (100%)	
BMI, kg/m^2	24.1 (5.1)	23.8 (5.3)	25.0 (4.5)	0.09
Family Monetary Support				0.993
Yes	64 (81%)	47 (81%)	17 (81%)	
No	15 (19%)	11 (19%)	4 (19%)	

[1] Data is reported as mean ± SD for continuous variables or as n (%) for categorical variables.
[2] Mann-Whitney tests and Chi square tests were used for continuous and categorical variables respectively. Where categories had a value less than 5, Fisher's Exact was used.

Combined daily fruit and vegetable intake and dairy intake were lower at each phase than the recommendations for this age group. From phase 1 to phase 2, dairy consumption had a marginally significant decrease by about one-tenth of a cup, but fruit and vegetable consumption did not significantly change.

The average estimated global PSQI score for sleep was high at both timepoints, despite underestimations due to a survey error described in the methods. Within person change from phase 1 to phase 2 was significant, with an average increase in score by 0.33 points. On the other hand, sleep duration averaged around 7 hours for both timepoints.

The average PSS score for stress during phase 1 was around 20 points, with a statistically significant average decrease at phase 2 by around 0.8 points. Most participants at both timepoints were categorized as "moderately stressed," with a small decrease in "high stress" individuals and a resulting increase in "low stress" individuals at phase 2. The average CES-D score for depression was also high, at around 20 for baseline with no statistically significant change at phase 2. Over half of participants were labelled as showing significant signs of depression at both phases. Participants had an average score of 1.9 and 1.8 at phases 1 and 2 respectively for the anxiety screeners, suggesting most participants struggle with at least two aspects of anxiety. There was no significant change in CES-D score between phases 1 and 2.

Table 2: Food insecurity, diet, sleep, mental health and academic outcomes for phases 1 and 2 alongside change from phase 1 to phase 2[1]

Variable	**Phase 1 n=79**	**Phase 2 n=68**	**Change from phase 1 to phase 2 n=77**	**P-Value[5]**
FOOD INSECURITY				
Food insecurity score	1.1 (2.1)	1.1 (2.2)	0.1 (0.6)	0.3
Food security categories				
Food secure	58 (73.4%)	53 (77.9%)		
Food insecure	21 (26.6%)	15 (22.1%)		
DIET				
Combined daily fruit and vegetable intake, cups	1.7 (0.8)	1.59 (0.7)	–0.10 (0.62)	0.225
Daily dairy intake, cups	1.1 (0.6)	1.0 (0.5)	–0.11 (0.43)	0.055
SLEEP				
Sleep quality score	8.5 (2.2)	8.8 (2.6)	0.33 (1.50)	0.030*
Sleep duration, hours	7.0 (1.3)	6.8 (1.3)	–0.11 (0.95)	0.148
MENTAL HEALTH				
Perceived stress score	19.8 (5.4)	18.3 (5.8)	–0.82 (3.99)	0.038*
Perceived stress severity levels				
Low stress	11 (13.9%)	16 (23.5%)		
Moderate stress	59 (74.7%)	46 (67.7%)		
High stress	9 (11.4%)	6 (8.8%)		
Depression score	19.6 (10.1)	20.0 (12.4)	1.08 (7.80)	0.731
Depression severity levels				
Not depressed	31 (39.2%)	32 (47.1%)		
Depressed	48 (60.8%)	36 (52.9%)		
Anxiety score	1.9 (1.0)	1.8 (1.1)	–0.03 (0.89)	0.399
ACADEMIC PERFORMANCE				
Self-report GPA	3.67 (0.35)	3.67 (0.33)	–0.01 (0.05)	0.094
University-report GPA	3.63 (0.4)	3.59 (0.5)	-0.05 (0.28)	0.797
Attention span during class, %				
Excellent/good	38 (48.1%)	35 (45.5%)	7 (9.1%)[2]	
Fair/poor	41 (51.9%)	42 (54.6%)	9 (11.7%)[3]	0.617
Frequency of missing classes				
Less than once a week or once a week	57 (73.1%)	46 (59.7%)	2 (2.63%)[2]	

More than once a week	21 (26.9%)	31 (40.3%)	3 (17.1%)[3]	0.005*
Ability to understand class material				
Excellent/good	68 (86.1%)	60 (77.9%)	6 (7.8%)[2]	
Fair/poor	11 (13.9%)	17 (22.1%)	12 (15.6%)[3]	0.157

[1] Data is reported as mean ± SD for continuous variables or as n (%) for categorical variables.
[2] The n (%) for individuals who changed from "fair/poor" or "more than once a week" to "excellent/good" or "less than once a week or once a week" respectively.
[3] The n (%) for individuals who changed from "excellent/good" or "less than once a week or once a week" to "fair/poor" or "more than once a week" respectively.
[5] T-tests and Wilcoxon Signed Rank tests were used for continuous and categorical variables respectively. When not normally distributed, Wilcoxon Signed Rank test was always used.

Self-reported GPA averaged around 3.67 for both timepoints with no significant difference. While university reported GPA was slightly lower, averaging around 3.60, there was no significant difference after the end of the semester. Just over half of participants rated their attention span during class on the lower end, fair/poor during both phases. Most participants showed no change in attention span between timepoints and there was no statistically significant change. When it came to missing required classes, most participants reported missing class less than once a week or around once a week, and most participants reported no change between timepoints. There was a significant change towards missing class more frequently during phase 2. Most students at both timepoints reported understanding their class material; although 12 participants (15.6%) changed status for the worse in phase 2, it was not significant.

An initial unadjusted analysis was performed to assess associations between baseline food insecurity status and various outcomes of interest. An adjusted analysis was performed thereafter, adjusting for the following potential confounders: gender, race, first generation student status, BMI at baseline and family financial support at baseline.

Table 3: Associations between food insecurity and diet, sleep, mental health, and academic performance by study timepoint[1]

	Unadjusted Analysis			**Adjusted Analysis**		
	Phase 1 n=77	Phase 2 n=77	Change n=77	Phase 1 n=77	Phase 2 n=77	Change n=77
DIET						
Combined daily fruit and vegetable intake (cups)	-0.5 (-0.88, -0.12)*	-0.5 (-0.82, -0.17)*	0.04 (-0.28, 0.36)	-0.59 (-0.97, -0.20)*	-0.52 (-0.86, -0.19)*	0.05 (-0.26, 0.37)
Daily dairy intake (cups)	-0.22 (-0.50, 0.06)	-0.2 (-0.44, 0.03)	0.1 (-0.12, 0.33)	-0.26 (-0.51, -0.02)*	-0.18 (-0.42, 0.05)	0.14 (-0.08, 0.37)
SLEEP						
Sleep quality score	1.3 (0.21, 2.39)*	1.34 (0.04, 2.64)*	0.16 (-0.62, 0.95)	1.33 (0.16, 2.50)*	1.44 (0.07, 2.82)*	0.17 (-0.65, 0.99)
Sleep duration (hours)	0.01 (-0.64, 0.67)	-0.02 (-0.70, 0.67)	-0.02 (-0.51, 0.48)	0.11 (-0.56, 0.79)	-0.02 (-0.75, 0.71)	-0.11 (-0.65, 0.43)
MENTAL HEALTH						
Perceived stress score	4.31 (1.74, 6.88)*	5.79 (3.01, 8.57)*	1.11 (-0.96, 3.17)	3.9 (1.27, 6.54)*	5.27 (2.31, 8.23)*	0.99 (-1.24, 3.22)
Depression score	7.55 (2.69, 12.42)*	11.59 (6.10, 17.08)*	3.34 (-0.65, 7.33)	7.19 (2.04, 12.35)*	11.34 (5.30, 17.39)*	3.67 (-0.71, 8.04)
Anxiety score	0.64 (0.14, 1.14)*	0.76 (0.23, 1.30)*	0.17 (-0.29, 0.64)	0.69 (0.18, 1.20)*	0.76 (0.20, 1.32)*	0.15 (-0.36, 0.66)
ACADEMIC PERFORMANCE						
Self-report GPA	-0.08 (-0.26, 0.10)	-0.13 (-0.31, 0.06)	-0.03 (-0.06, -0.01)*	-0.03 (-0.22, 0.16)	-0.07 (-0.26, 0.13)	-0.03 (-0.06, 0.00)
University-report GPA	-0.16 (-0.38, 0.07)	-0.09 (-0.40, 0.23)	0.07 (-0.10, 0.23)	-0.10 (-0.32, 0.13)	0.01 (-0.30, 0.33)	0.08 (-0.08, 0.25)

[1] Data is reported as means with 95% CI for continuous variables or as odds ratios with 95% CI for categorical variables. Linear regression was used.
[2] Adjusted for gender, race, first generation student status, BMI at baseline and family financial support at baseline.

Table 4: Associations between food insecurity and academic performance by study timepoint[1]

	Unadjusted Analysis		**Adjusted Analysis**	
	Phase 1 n=77	Phase 2 n=77	Phase 1 n=77	Phase 2 n=77
ACADEMIC PERFORMANCE				
Fair/poor attention span during class	2.3 (0.81, 6.52)	3.33 (1.07, 10.40)*	2.71 (0.88, 8.33)	4.53 (1.27, 16.25)*
Missing class more than once a week	2.08 (0.71, 6.11)	1.3 (0.46, 3.65)	2.7 0.81, 8.97)	1.61 (0.53, 4.91)
Fair/poor ability to understand class material	1.04 (0.25, 4.36)	3.56 (1.13, 11.15)*	1.01 (0.21, 4.83)	2.62 (0.67, 10.26)

[1] Data is reported as means with 95% CI for continuous variables or as odds ratios with 95% CI for categorical variables. Logistic regression was used.
[2] Adjusted for gender, race, first generation student status, BMI at baseline and family financial support at baseline.

In both the unadjusted and adjusted models, combined daily fruit and vegetable intake was significantly associated with food insecurity status such that food insecure participants consumed on average around half a cup fewer fruits and vegetables. Food insecurity status was only significantly associated with daily dairy intake during phase 1 in the adjusted analysis, where food insecure participants consumed on average a quarter cup less dairy a day.

Food insecurity status predicted a 1.3 increase in sleep quality score on average, meaning worse sleep outcomes in food insecure students in phases 1 and 2 across both models. Sleep duration was not significantly associated with food insecurity status. As with diet, food insecurity status was not able to predict the change in outcomes between phases 1 and 2 in either model.

All mental health outcomes investigated were correlated with baseline food insecurity status at both timepoints in both models. Food insecurity was always correlated with higher scores, and thus worse outcomes. The magnitude of the increase was consistently greater for phase 2 than phase 1. For example, food insecure participants had depression scores 7.19 units higher during phase 1 and 11.34 units higher for phase 2 in the adjusted model; similarly, food insecure participants had scores 3.9 units higher on the PSS during phase 1 and 5.27 units higher during phase 2. Food insecurity status could not predict this change in outcomes between timepoints, suggesting its attribution to timepoint alone or another covariate not considered here.

There was no statistical significance between food insecurity status and self-reported GPA, although it did predict a minor decrease in GPA between timepoints in the unadjusted model; the significance disappeared in the adjusted model likely indicating a

lack of overall significance. University-reported GPA neared significance but did not achieve it. Food insecurity was significantly related to attention span and keeping up with class material at phase 2 in the unadjusted model, but the latter variable's relationship was attenuated in the adjusted model. In each case, food insecure participants reported more negative outcomes (e.g. they were 4.53 times as likely to report having fair/poor attention span during phase 2 in the adjusted model).

CHAPTER FOUR

Discussion

Food insecurity prevalence was at the lower end of the previously estimated range for college students, but it was still over double the US household average at both timepoints. This might be attributable to the demographic makeup of our sample, to the timing of Fall break during our survey, to the use of the 10-item USDA Food Security Survey Module or to the small sample size. Few variables changed significantly from phase 1 to phase 2, but this might be because the phases were close together. Similarly to food insecurity prevalence, the timing of Fall break might have skewed results. Fruit and vegetable intake, all mental health measures, and attention span were significantly associated with food security status in the unadjusted and adjusted models; only ability to understand course material was significant in the former and not the latter. GPA was not associated with food insecurity status nor did it change significantly over time in any analysis, suggesting it might not be sensitive enough a predictor of academic outcomes for a single semester.

Food Insecurity Prevalence

Following our predictions based on previous literature, food insecurity in this sample was higher than the estimated household average; in fact, it was over double. This suggests that even universities with anti-hunger resources (Gaines et al., 2014; Martinez et al., 2021) are not completely protected from the drastically high prevalence of food

insecurity in undergraduate college students. While it is impossible to pinpoint why the food insecurity prevalence found here was lower than the average estimated prevalence found by others (Nikolaus et al., 2020), there are a few potential reasons.

First, our sample was primarily white, non-Hispanic, received financial support from their families and did not receive free/reduced school meals in high school, suggesting that they are less likely to come from a background of chronic food insecurity and thus are less likely to experience food insecurity themselves (Laska et al., 2021; Nikolaus et al., 2020). Second, unlike many earlier studies, this one used the full 10-item Adult Food Security Survey Module instead of the 6-item short form (Bruening et al., 2018; Nikolaus et al., 2020); the latter form has been recently shown to overestimate food insecurity prevalence in all populations, including college students.

Finally, many school loans, grants, other financial aid and meal swipes are designed for the entire year but handed out at the beginning of the Fall semester. This requires students to monitor and plan out their use of these resources, but students might use them up immediately, protecting themselves from food insecurity in the Fall, but increasing their risk in the Spring. While second- and third-year students should be familiar with this cycle, individuals from food insecure backgrounds may have learned negative coping behaviors like the feast-famine cycle (Bruening et al., 2018; el Zein et al., 2019). This theory suggests that individuals who have experienced food insecurity are more likely to binge eat or to eat without consideration for the future whenever food and resources are available, followed by a resulting famine period defined by food insecurity. Altogether this warrants a comparison between food insecurity in the Fall and in the

Spring, using the 10-item adult food insecurity survey module, especially for students using meal swipes or receiving other kinds of year-based aid.

A consideration for food insecurity's lack of change in prevalence over time is the timing of school holidays. At this university, the Fall break is 1 week (5 weekdays off) over Thanksgiving at the end of November, right before participants in this study responded to the phase 2 survey. Many students go home for the break, where they are less likely to experience food insecurity, among other outcomes discussed later. Due to the saliency and recency of break, it is possible that participants reported significantly lower food insecurity scores for the entire month, attenuating the expected increase in food insecurity prevalence at the end of the semester.

Another potential reason could be the Food Insecurity Survey Module itself, since it only collects data on financial barriers to food access and hunger. Since some college students may have food insecurity more as a result from food access (e.g. lack of transport to grocery stores, lack of cooking facilities, campus cafeterias having inaccessible hours), this survey module would fail to capture those difficulties. Further research is needed comparing food insecurity prevalence during the Fall and Spring semesters, and students might require additional food insecurity questions than the 10-item Adult Food Insecurity Survey Module can address.

Finally, in this study, all participants below food secure were pooled for analysis (e.g. marginally food insecure, moderately food insecure, and severely food insecure), but a larger study with more power should assess differences between these groups overtime. Since moderate and severe food insecurity are more likely to be chronic, or to last for multiple periods of follow up, it is possible there is fluctuation in students labelled food

secure and marginally food insecure (Hanson & Connor, 2014). These students may be less likely to access food resources or to have successful coping mechanisms related to food insecurity, and therefore may benefit from specific targeting by anti-hunger programs.

We collected demographic data based on potential covariates for food insecurity in undergraduate college students. While some of them approached significance, such as first-generation student status and BMI, none of them were significant. This is likely due to the small sample lacking in diversity. For example, race responses had to be pooled into "Caucasian/white" and "non-Caucasian/white" because of the relatively great majority of participants who chose the former. However, not all racial minorities experience food insecurity to the same degree; it is possible the relatively low prevalence among Asians (Nikolaus et al., 2020) is disguising the relatively high prevalence among African Americans/blacks. Therefore, when considering covariates to include in the regression models, we chose based off of evidence in previous literature. We did not include ethnicity as a covariate because the number of Hispanic participants was less than 5. We also did not include place of residence because in previous studies the difference between living on-campus and off-campus has been attributed to first-year students primarily living on-campus and older students primarily living off-campus, which was controlled for in our sample.

Before assessing the relationship between food insecurity status at baseline and the outcomes of interest, we calculated within-person change to assess how these variables changed over time generally. Only overall sleep quality, the PSS and frequency of missing class were significantly changed over time. This supports previous literature that sleep outcomes (Arenas et al., 2019; Ding et al., 2015) and stress (Arenas et al.,

2019) tend to worsen as the semester comes to an end, likely because of looming final projects and exams. Students may also skip class more frequently to work on said projects and study, or because they are burnt out.

However, this means that unlike expected, depression and anxiety scores did not increase as time went on; nor did sleep duration decrease as the end of the semester neared. This population reported high depression symptomology at both timepoints, with average scores over 20 and greater than 50% of all participants classifying as depressed. When comparing between timepoints, these already extreme scores could cause the change over time to appear small and insignificant in contrast. Reported sleep durations were average for this age group, at around 7 hours a night (Ding et al., 2015; Lund et al., 2010). Given the significant change in overall sleep quality, a separate variable likely influenced the score enough to change it over the course of the semester. Similarly to food insecurity status, it is possible the recency of Fall break provided a protective effect for all variables, so that only outcomes with large changes (e.g. sleep quality score, perceived stress score and missing class) had a noticeable difference. College students tend to eat more home-cooked and healthy meals over break, to feel support from family members or friends, and to sleep more (Coughenour et al., 2021).

Students were more likely to miss classes as the semester progressed, but none of the other academic outcomes changed significantly. Although finding a lack of change in GPA was surprising given previous literature, it is possible that a single semester is not long enough to reflect any significant change in GPA. Although we theorized that burn out might cause students to have worse attention span during class and difficulty keeping up with class material, these findings suggest that students generally are able to maintain

these abilities through the end of the semester. It is once again possible that the proximity of Fall break might have influenced these outcomes, since students may have felt refreshed after break and failed to consider the entire previous month rather than only the previous week.

Finally, we used regression models to assess the associations between food insecurity status at baseline with the outcomes of interest and with the change in those outcomes between timepoints. Across the board, food insecurity was associated with poorer outcomes in each instance. Many of the categories were statistically significant and maintained significance in the adjusted model.

Food Insecurity and Diet

For example, food insecure participants consumed on average half a cup less of fruits and vegetables at both timepoints. This agrees with previous literature suggesting that food insecure students have lower quality diets (Hanson & Connor, 2014; Larson et al., 2009), although it is not clear if the lower quality is due to worse resources, access, or habit learned while growing up.

Unlike in previous literature on American adults and college students (Hanson & Connor, 2014; Mei et al., 2021), this sample did not show food insecure participants at increased risk for lowered dairy consumption a day. This could be influenced by the overall very low daily intake of dairy, which was averaged at about 1 cup a day for all participants. Further, the NHANES Diet Screener Questionnaire specifically asked participants not to include alternative milks such as almond, cashew, or blends into their

responses; these alternative milks are very popular with college students but tend to cost more than cow's milk. It is possible that food secure participants have chosen to switch to costly alternative milk options, thus lowering their dairy intake per this screener, whereas food insecure participants stick to cheaper cow's milk, inflating their intakes in comparison.

In both cases, food insecurity status was unable to significantly predict a change in dietary intake from phase 1 to phase 2. This means that food insecure students reflected the same lack of change shown in the overall group. Similarly, it is possible a change occurs for students facing the most severe form of food insecurity, but our sample size was too small to consider each level separately.

Food Insecurity and Sleep

Food insecure participants also had significantly increased sleep quality scores in both models, indicating worse sleep outcomes compared to their food secure peers. This reflects what previous literature exists on food insecurity and sleep in the general population (Arenas et al., 2019; Ding et al., 2015; Troxel et al., 2020)and in college students (Phillips et al., 2017). Important to note, however, is that the difference was only an average 1.33 unit in the score. Given the need to estimate the global PSQI score for sleep quality because of a survey error, it is difficult to interpret these results with practical significance; previous literature suggests that food insecure students have on average worse habitual sleep efficiency than food secure ones (Gaultney, 2016; Orzech et al., 2011). This could have increased the gap between the food insecure and food insecure

in our sample and suggests our data has not been skewed since we were able to use difficulty falling asleep in scoring. However, given that the data was not collected, it is impossible to know for sure; although unexpected, it is possible food insecure participants had overall better sleep efficiency, closing the gap between them and their food secure peers. As analyzed here, it is clear the difference in scores was not significantly attributable to sleep duration, which did not significantly change by food security status.

Although sleep quality was shown to change significantly from phase 1 to phase 2, food insecurity status was not able to predict this change. This means that the difference between scores at each phase is attributable to something other than food insecurity. Most likely, sleep quality decreased as students prioritized academic performance above sleep at the end of the semester, but it is impossible to say for sure.

Food Insecurity and Mental Health

Food insecure participants had increased mental health scores, indicating poorer outcomes, for all mental health measures used here. The magnitude of the increase was minorly attenuated using the adjusted model (e.g. the unadjusted model had average score increases less than half a point greater than the adjusted one). It follows with previous literature that food insecure college students experience worse mental health, including stress, depression, and anxiety (Arenas et al., 2019; Nyer et al., 2013; Wolfson et al., 2021). Food insecurity probably acts as its own stressor and burden on individual's mental load, which food secure individuals do not have to carry. Food insecurity may

evoke feelings of shame or unworthiness and feelings of isolation, increasing the likelihood for depression (Meza et al., 2019). Hunger and poor sleep can both lead to depression-like symptoms such as lethargy and lack of motivation. Whereas worry about where the next meal will come from can lead to anxiety, which can become endemic to all facets of life if food insecurity is chronic.

In the current literature stress is frequently combined with anxiety into one measure despite their differences. However, it is important to note that the two are related, so it makes sense that students with high perceived stress also experience higher levels of anxiety on average. Further, while depression is typified by apathy and anxiety by high energy, the two are also interrelated; individuals with one are more likely to have the other than others without any mental health disorders.

Food Insecurity and Academic Performance

Unexpectedly, food insecurity was not significantly associated with GPA scores. Because college students may report higher GPAs than they actually have, this study used objective, university-reported GPA as well. While the mean scores were slightly lower overall than reported by students, it seems most students accurately reported their GPA. It was surprising that university-reported GPA similarly was not significantly associated with food insecurity. One reason for this might be the alternative grading implemented during the COVID-19 pandemic. Alternative grading at the Pennsylvania State University allowed students to select any course from that semester and receive an alternative grade that did not affect their GPA. SAT or satisfactory was given to students

with a letter grade of C or higher, V was given to students with a letter grade of D or higher, and Z was given to students with an F letter grade. Designations were to allow students to still use courses to meet program requirements (e.g. V was a passing grade for credit but was not good enough for most programs' core courses which require a grade of C or above). Although alternative grading was not in effect the semester this study was implemented, it was the previous 3 semesters. This likely diminished the association with food security status and the difference over time, since students were more likely to have more similar and extreme GPA scores at phase 1. Considering our small sample size, short time period and the effect of alternative grading, it is most likely the extensive literature suggesting the two are linked holds true (Weaver et al., 2020).

Although GPA is the most widely used measure of academic outcomes, it does not always represent difficulties students have, especially over the course of only one semester. Like dropping a course or dropping out of college entirely, GPA is more sensitive as a marker over the entire degree program, although it has been called into question for that as well (van Woerden, Hruschka, & Bruening, 2019; Weaver et al., 2020). Generally, it is possible to receive high grades in some classes without an understanding of the material; it is also possible to receive low grades despite understanding the material, due to poor attendance, turning homework in late, or testing poorly. It is also possible to spend more energy studying, attending reviews, etc. to make up for other difficulties such as poor attention span; however, this is at the cost of time, cognitive and sometimes financial resources.

Therefore, this study used novel questions to assess academic outcomes besides GPA. Food insecurity was associated with worse attention span and difficulty being able

to understand class material in the unadjusted model, but only at phase 2. Only the association between attention span and food insecurity during phase 2 remained in the adjusted model; in this case, food insecure participants were around 4.5 times as likely to rate their attention span during class as fair/poor instead of as excellent/good. Further, the odds actually increased after adjusting for covariates. It was expected that food insecure students would struggle with attention span because of worse mental health, sleep and hunger, but it was expected at both timepoints. Although this sample was too small to analyze for associations between food insecurity severity, it is possible that worse severity at the end of the semester increased the magnitude and significance of its effect on attention span.

It is not clear why food insecurity was not significantly associated with ability to understand class material at phase 2 nor which covariate attenuated the association seen in the unadjusted model. Further, it was surprising that food insecurity had no significant association with missing class, which suggests food insecure students prioritize attendance over other needs even when time and food might be scarce. Given that these are novel variables, there is no previous literature drawing conclusions between them and food insecurity; this sample suggests that food insecure students participate in class and are able to understand their course material, at least as well as their food secure peers. Differences seen in GPA scores in previous literature then might be attributable to poor test taking, failure to turn in assignments, etc. rather than to aptitude or attendance.

Strengths and Limitations

This study utilized a longitudinal design to assess within person differences for all variables of interest over the course of a semester. The 10-item Adult Food Security Survey Module was used as a better validated and more sensitive marker of food insecurity status in this population instead of the 6-item short form. Similarly, while self-reported and objective university-reported GPA were collected for analysis, this study included novel questions to assess more specifically how food insecurity might influence academic outcomes through attention span, frequency of missing class, and ability to understand class material.

It appears that a single semester may have been too short to show changes in food insecurity status and academic outcomes. Because of this, we were unable to assess mediation effects of diet, sleep and mental health between food insecurity and academic outcomes suggested in previous literature. On the other hand, the small sample size may have simply failed to capture the change in food security status that occurs in a minority of students. While the small sample size means participants were not ethnically or racially diverse, it allows the study to provide greater inference for those it did include, who were primarily young white women. Another complicating factor is the timing of Penn State's Fall break near the end of the Fall semester, which might differentiate outcomes between Fall and Spring, and between Penn State and other universities.

As mentioned in the methods, there was an error in the survey that meant participants did not answer one of the PSQI items needed to calculate its global PSQI score. While the results here do not represent the true global PSQI scores of these

participants, it was still useful in drawing associations between food insecurity and sleep. Further, the recommended cut off for "poor sleep" using the global PSQI is scores greater than 5, which almost all participants in this study met regardless of this underestimation.

Conclusions

In sum, we found that food insecurity prevalence was high, 26.6% of the sampled undergraduate students at phase 1 and 22.1% at phase 2, which is over double the national household average. Food insecurity was significantly and negatively associated with fruit and vegetable intake, all mental health measures including stress, depression and anxiety, and attention span during class. Food insecure students attend class and are able to keep up with course material just as well as their food secure peers; any differences in GPA or other academic outcomes noted previously may be attributable to food insecurity or another. Campus resources should focus on making anti-hunger aid easily accessible as well as plentiful. Already many universities offer mental health support to individuals accessing anti-hunger resources, but it would help to offer anti-hunger aid to all students accessing mental and sleep health support too.

APPENDIX

Survey Questions

1. Demographics
   1.1. What is your gender?
      a. Man
      b. Woman
      c. MTF Transgender
      d. FTM Transgender
      e. Agender
      f. Non-binary or other gender non-conforming
      g. Other (please specify):
   1.2. What is your age?
   1.3. What is your ethnicity?
      a. Hispanic (1)
      b. Non-Hispanic (2)
      c. Choose not to answer (3)
   1.4. What is your race?
      a. White or Caucasian (1)
      b. Black or African American (2)
      c. American Indian or Alaskan Native (3)
      d. Asian (4)
      e. Pacific Islander (5)
      f. Bi or multiracial (please define:) (6)
      g. Other (7)
      h. Choose not to answer (8)
   1.5. Are you a first-generation college student?
      a. Yes (1)
      b. No (2)
      c. Choose not to answer (3)
   1.6. How would you describe your current living location while you are attending college?
      a. On-campus (1)
      b. Off-campus (2)
      c. At home with family (3)
   1.7. While in high school, did you participate in free/reduced price school lunch program?
      a. Yes (1)
      b. No (2)
      c. I’m not sure (3)

d. Choose not to answer (4)

1.8. Are you an international student?

a. Yes (1)
b. No (2)
c. Choose not to answer (3)

1.9. Are you a veteran?

a. Yes (1)
b. No (2)
c. Choose not to answer (3)

2. Food Insecurity

2.1. 10-Item Adult Household Food Security Survey Module

2.2. Do you use meal swipes?

a. Yes (1)
b. No (2)
c. Choose not to answer (3)

2.3. *(IF 3.9 = 1)* Did you ever not eat when you were hungry to save meal swipes to make them last?

a. Yes (1)
b. No (2)
c. Choose not to answer (3).

3.10.1 *(IF 3.10 = 1)* Did you ever worry about running out of meal swipes before the semester is over?

d. Yes (1)
e. No (2)
f. Choose not to answer

3. Academic Progress

3.1. How would you rate your overall progress in school?

a. Excellent (1)
b. Good (2)
c. Fair (3)
d. Poor (4)

3.2. How regularly do you miss classes that you are required to attend?

a. Less than once a week (1)
b. Around once a week (2)
c. Around twice a week (3)
d. More than twice a week (4)

3.3. How would you rate your attention span in class?

a. Excellent (1)
b. Good (2)
c. Fair (3)
d. Poor (4)

4.4.1 *(IF 4.4 = 1 or 2)* Please select all of the following reasons you find it difficult to pay attention in class. Check ALL that apply:

e. Hunger (1)
f. Tiredness (2)
g. Lack of interest (3)
h. Social media/texting (4)
i. Online shopping (5)
j. Anxiety (6)
k. Multitasking for coursework (e.g. working on homework for other classes, reading articles related to this or other classes, etc) (7)
l. Remote learning distractions (e.g. noises at home, family members, … (8)
m. Other (please specify) (9)

3.4. How would you rate your ability to understand what is being taught in your classes?

a. Excellent (1)
b. Good (2)
c. Fair (3)
d. Poor (4)

3.5. How would you rate your ability to keep up to date with your classes?

a. Excellent (1)
b. Good (2)
c. Fair (3)
d. Poor (4)

3.6. What is your overall GPA from last semester? (For phase 2: What do you expect your overall GPA will be at the end of this semester?)

4. Anthropometrics/Health

4.1. What is your weight in pounds?
4.2. What is your height in inches?
4.3. Cohen Perceived Stress Scale
4.4. Center for Epidemiology Studies-Depression
4.5. Did you feel continually worried or anxious about a number of events or activities in your daily life?

a. Yes (1)
b. No (2)
c. Choose not to answer (3)

4.6. Did you have times when you felt a sudden rush of intense fear or discomfort?

a. Yes (1)
b. No (2)
c. Choose not to answer (3)

4.7. In social situations where you might have been observed or evaluated by others or when you were meeting new people, did you feel fearful, anxious or nervous?

a. Yes (1)
b. No (2)

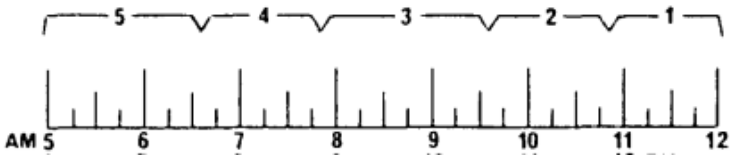
c. Choose not to answer (3)

4.8. Pittsburgh Sleep Quality Index

4.9. 8-Item Reduced Cambridge-Hopkins Restless Leg Syndrome Scale

4.10. Reduced Horne-Östberg Morningness-Eveningness Scale

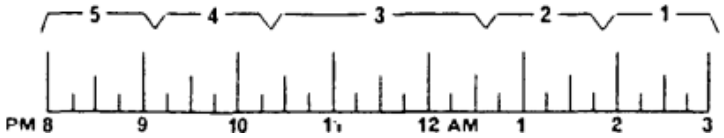
4.11. Considering only your own "feeling beat" rhythm, at what time would you get up if you were entirely free to plan your day?



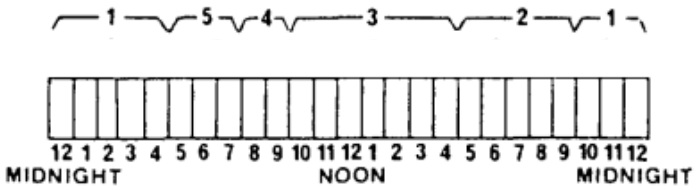
4.12. During the first half hour after having woken in the morning, how tired do you feel?

a. Very tired (1)
b. Fairly tired (2)
c. Fairly refreshed (3)
d. Very refreshed (4)

4.13. At what time in the evening do you feel tired and as a result in need of sleep?



4.14. At what time of day do you reach your "feeling best" peak?



4.15. One hears about "morning" and "evening" types of people. Which ONE of these types do you consider yourself to be?

a. Definitely a "morning" type (6)
b. Rather more a "morning" type than an "evening" type (4)
c. Rather more an "evening" type than a "morning" type (2)
d. Definitely an "evening" type (0)

5. Food Behaviors

5.1. National Health and Nutrition Examination Study – Dietary Screener Questionnaire

5.2. On average, how many days **<u>in the past week</u>** did you eat breakfast?

a. Never (0 days) (1)
b. Occasionally (1-2 days) (2)
c. Sometimes (3-4 days) (3)
d. Mostly (5-6 days) (4)
e. Always (7 days) (5)

Please state how well you agree or disagree that the following describes you:

5.3. It is hard for me to find time to sit down and eat a meal.
   a. Strongly Agree (1)
   b. Agree (2)
   c. Neutral (3)
   d. Disagree (4)
   e. Strongly Disagree (5)

5.4. I usually eat dinner with other people.
   a. Strongly Agree (1)
   b. Agree (2)
   c. Neutral (3)
   d. Disagree (4)
   e. Strongly Disagree (5)

5.5. I tend to eat meals on the run.
   a. Strongly Agree (1)
   b. Agree (2)
   c. Neutral (3)
   d. Disagree (4)
   e. Strongly Disagree (5)

5.6. I am able to eat meals regularly (at the same times each day).
   a. Strongly Agree (1)
   b. Agree (2)
   c. Neutral (3)
   d. Disagree (4)
   e. Strongly Disagree (5)

5.7. Regular meals are important to me.
   a. Strongly Agree (1)
   b. Agree (2)
   c. Neutral (3)
   d. Disagree (4)
   e. Strongly Disagree (5)

5.8. **Over the past week**, how many times did you or someone else you live with cook food for dinner or supper at home?
   a. Never (1)
   b. 1-2 times (2)
   c. 3-4 times (3)
   d. 5-6 times (4)
   e. More or equal to 7 times (5)

5.9. What are the names of the stores or markets where you shopped the most, second most and third most for food (not including beverages) **over the past 4 weeks**?

Please be as specific as possible, e.g. if Target specify the "Target on Atherton St" vs "Target on Beaver avenue"

1. _____
2. _____
3. _____

5.10. How often did you shop at your number 1 store or market **over the past 4 weeks**?

a. Less than once (1)
b. Once or twice (2)
c. Three or four times (3)
d. Five or six times (4)
e. Seven or more times (5)

5.11. How often did you shop at your number 2 store or market **over the past 4 weeks**?

a. Less than once (1)
b. Once or twice (2)
c. Three or four times (3)
d. Five or six times (4)
e. Seven or more times (5)

5.12. How often did you shop at your number 3 store or market **over the past 4 weeks**?

a. Less than once (1)
b. Once or twice (2)
c. Three or four times (3)
d. Five or six times (4)
e. Seven or more times (5)

5.13. What transportation types are regularly available to you? *(select as many as apply)*

a. Personal car, truck or other vehicle (1)
b. Ride in a car, truck or other vehicle driven by a friend/family member (2)
c. Ride in a taxi, Uber, Lyft or similar (3)
d. Ride on a bus (4)
e. Walking or travel by foot (5)

5.14. How much of a problem would you say that lack of access to adequate food shopping is in your neighborhood?

a. Very serious problem (1)
b. Serious problem (2)
c. Neutral (3)
d. Not a problem (4)
e. Very much not a problem (5)

5.15. How often **over the past week** did you eat at residential PSU dining commons?

a. Never (1)
b. 1-2 times (2)
c. 3-4 times (3)
d. 5-6 times (4)
e. More than or equal to 7 times (5)

5.16. How often **over the past week** did you eat out at restaurants (please include delivery services like *Grubhub, Uber Eats, DoorDash* etc?

a. Never (1)
b. 1-2 times (2)
c. 3-4 times (3)
d. 5-6 times (4)
e. More than or equal to 7 times (5)

On another topic…

5.17. Are you aware of resources on campus for students who have difficulty receiving enough food?

a. Yes (1)
b. No (2)
c. Choose not to answer (3)

5.41.1 (IF 5.41 = 1) What resources? Please specify:

5.41.2 (IF 5.41 = 1) How many times have you used resources on campus that provide students food?

a. Once (1)
b. A few times (2)
c. Frequently (3)
d. Never (4)
e. Choose not to answer (3)

6. Financials

On another topic…

6.1. Which term best describes your employment status over the **past 4 weeks**?

a. Unemployed (1)
b. One or more part-time jobs (2)
c. One full-time job (3)
d. Other (Please specify) (4)

6.2. Do you currently receive income from some type of financial aid like a scholarship, grant, private or federal loan?

a. Yes (1)
b. No (2)
c. Choose not to answer (3)

7.2.1 *(IF 7.2 = 1)* What type of financial aid do you receive? Check **ALL** that apply.

a. Graduate Stipend (1)
b. Federal Loan (2)
c. Personal Loan (3)
d. Scholarship (4)
e. Pell grant (5)
f. Tuition remission (6)
g. Other (please specify) (7)

6.3. Did you receive financial support from family over the **past 4 weeks**?

a. Yes (1)
b. No (2)
c. Choose not to answer (3)

6.4. Over the **past 4 weeks,** have you received Supplemental Nutrition Assistance Program (SNAP) benefits (Food Stamps)?

a. Yes (1)
b. No (2)
c. Choose not to answer (3)

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Academic Vita

Education

The Pennsylvania State University, State College, PA Expected Graduation May 2022

Master of Science, Nutritional Sciences

Bachelor of Science, Nutritional Sciences (Dietetics), Honors

Bachelor of Arts, Letters Arts and Sciences (Psycholinguistics)

Minor, German

IES Abroad, Berlin, Germany

Coursework: Berlin Lit. and Adv. German Language May 2018 - Jul 2018

Nutrition Related Experience

Department of Health and Human Development, State College, PA

Research and Teaching Assistant Aug 2019 - present

- Designing and conducting a nutritional epidemiological study, including extensive literature review and academic paper writing
- Collaborating on other research projects in the lab and mentoring undergraduates in research
- Leading discussions to develop critical thinking in an honors undergraduate nutrition class
- Adviser: Dr. Muzi Na

SweetFrog, State College, PA

Assistant Manager Apr 2019 - present

- Training, supervising and scheduling approx. 15 workers for all shifts
- Buying and preparing fresh produce as required for expected demand
- Answering customer questions about ingredients/allergens and organizing fundraisers
- Disassembling, cleaning and sanitizing yogurt machines, standing fridges and freezers and a walk-in fridge while keeping all food within food safe temperatures

Café Laura, State College, PA

Student Worker (Hospitality Management 330) Jan 2020 - Apr 2020

- Used safe handling practices to prepare and serve food while minimizing cross contamination
- Planned a menu to limit food cost and waste, wrote standardized recipes and managed 13 other students in preparing and serving the menu
- Completed ServSafe class activities but was unable to sit for the exam due to COVID-19

Penn State Hillel, State College, PA

Chicken Soup Hotline Student Manager Jan 2018 - Mar 2020

- Standardized the recipes used and modified them based on customer feedback
- Trained up to 5 other students at once to safely and efficiently prepare, store, and deliver soup

- Organized incoming orders and scheduled approx. 7 student deliverers for variable loads each day
- Handled food for specialty diets, including Kosher and vegetarian

Other Work Experience

Center for Language Science, State College, PA

Research Assistant under Dr. Frances Blanchette Oct 2018 - Aug 2019

- Created and programmed all experimental materials for Qualtrics and eye-tracking software
- Scheduled, obtained informed consent and led 35 participants through the eye-tracker survey

IES Abroad, Berlin, Germany

Blog Writer May 2018 - July 2018

- Wrote and designed 6 blog posts for the IES Abroad website about experiences travelling to and being in Berlin and studying a foreign language abroad: www.iesabroad.org/blogs/author/660331

Additional Skills

- Highly proficient in REDCap and Qualtrics survey design
- Skilled in website design using Wordpress and document design
- Experienced in Zoom to schedule, hold and present both meetings and webinars
- Limited working proficiency in German

Awards

- Nutritional Sciences Student Marshall 2022
- Letters, Arts and Sciences Student Marshall 2022
- Summer Research Grant (Health and Human Development College) 2021
- Schreyer Honor Award (Schreyer Honors College) 2017 - 2021
- Goldstein Honor Award (Schreyer Honors College) 2017 - 2021
- Got Grit Award (the Health and Human Development College) 2021
  Awarded to one student in the college who shows true dedication and perseverance.
- Ho Award in Nutrition (the Health and Human Development College) 2019
  Awarded to one faculty-nominated student who demonstrates potential for professional success.