FOOD INSECURITY AND OBESITY: EXPERIENCE FROM AN ACADEMIC WEIGHT MANAGEMENT CLINIC

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Introduction

Obesity is a state of increased body weight that may increase the risk of various health conditions. There are a number of treatment options available, including lifestyle and behavior modification, pharmacotherapy, and bariatric surgery. Interestingly, some researchers have found that food insecurity, a condition characterized by having limited access to safe and nutritious foods, is associated with a higher risk of obesity. There are a number of differences between those with food security and those with food insecurity, which may contribute to this risk difference. These differences include both societal and personal factors, such as food access, food cost, eating patterns and behaviors, dietary quality, and stress. In this literature review, the problems of obesity and food insecurity will first be discussed individually and then they will be brought together to consider how they interact.

Obesity

Obesity is a condition of increased body weight, specifically adipose tissue, which may predispose individuals to numerous adverse health consequences. Both the World Health Organization (WHO) and the Centers for Disease Control and Prevention (CDC) define obesity as a body mass index (BMI) greater than or equal to 30 kg/m^2.[1,2] Obesity can be subdivided into three categories, Class 1 (BMI of 30 to < 35), Class 2 (BMI of 35 to < 40), and Class 3 (BMI ≥ 40).[1] Though the term “obesity” and this definition are commonly used, they are problematic in a few ways. The term “obesity” carries a large stigma in the public, which negatively affects the perception and self-esteem of those with obesity.[3] Furthermore, the use of a term based solely on an anthropometric measurement disconnects obesity from the health of individuals.[3] BMI may not be a good predictor of health status as cut-points vary based on ethnicity, the amount of muscle mass can influence the value regardless of adiposity, and it

ignores the distribution of body fat, which plays a role in health consequences.[3] To address this problem, the American Association of Clinical Endocrinologists and the American College of Endocrinology (AACE/ACE) have coined the term Adiposity-Based Chronic Disease (ABCD). This term indicates a precise pathophysiologic basis and explicitly identifies obesity as a chronic disease that can lead to characteristic adiposity-based complications.[3] It also avoids the stigma and confusion related to the term "obesity."[3] However, because of the common use of the term "obesity" and its definition based on BMI throughout the literature, they will be used in this thesis.

The prevalence of obesity around the world has doubled from 1980 to 2014.[2] Worldwide, 11% of men and 15% of women were considered obese in 2014.[2] The prevalence of obesity in the United States (US) mirrors these worldwide trends. There was little change in the prevalence of obesity from 1960 through 1980, but that was followed by significant increases in the years between 1980 and 2000.[4,5] Since 2000, the prevalence of obesity has leveled off and there have been small to no increases between 2000 and 2014.[5,6] Despite improvements in the prevalence of obesity, a large proportion of the US adult population is still affected by obesity; between 2011 and 2014, 36.5%, of the US adult population was considered obese.[6] This prevalence was higher among women (38.3%) compared to men (34.3%) and higher among Hispanic (42.5%) and non-Hispanic black adults (48.1%) compared to non-Hispanic white adults (34.5%).[6] Though there has been some plateauing of the prevalence of obesity more recently, some have predicted that the prevalence of obesity will rise to between 42% and 51% of the US population by 2030.[7]

Obesity is an issue of concern because it may increase the risk of type 2 diabetes, hypertension, dyslipidemia, coronary heart disease, stroke, cancer, respiratory problems, sleep apnea, and osteoarthritis.[2,8,9] However, the impact of adiposity on health varies based on the quantity and distribution of adipose

tissue. For example, accumulation of fat in the abdominal region is related to insulin resistance, type 2 diabetes, and cardiovascular disease.[3] Because of the negative effects on health that adipose may cause, obesity is estimated to cost approximately 9% of annual medical expenses in the US, about $147 billion each year.[7] Per-patient medical expenditures are estimated to be $3,559 higher in those with obesity compared to those who do not have obesity, due to increases in inpatient services, physician visits and outpatient services, and prescription medications.[8,10] Due to the increased risk of health consequences and increased health care costs, it is important to understand the factors that may contribute to obesity and the treatment options that are available.

Contributors to Obesity

Societal and Environmental Factors. Many factors play a role in the development of obesity, including the environment in which an individual lives. One of these factors is the built environment, referring to all places built or designed by people.[11] This includes buildings, parks, trails, sidewalks, and transportation systems. The built environment plays a role in obesity risk in a number of ways. For example, those living in areas with greater availability and proximity to recreation facilities have been found to participate in more physical activity compared to those with less availability and proximity to these facilities.[11] Furthermore, those that had perceived access to parks and trails were two times more likely to meet physical activity guidelines compared to those who did not feel these resources were available.[12] Simple access may not be enough though; design and maintenance are also important if these environmental factors are to benefit the public. For example, parks with courts, playgrounds, and soccer fields have been found to lead to more energy expenditure compared to parks with baseball fields, picnic areas, and open areas.[13] Also, trails were more likely to be used if they provided mixed views, streetlights, good trail conditions, and

facilities.[14] There are also neighborhood factors that can influence the amount of physical activity that an individual participates in. Those living in neighborhoods with sidewalks, adequate lighting, and pedestrian safety from traffic have higher physical activity compared to those living in areas without these features.[11] Finally, those with nearby bus and rail stops and those who use public transportation have been found to be more active compared to others, likely due to walking to and from public transportation stops.[11]

Another environmental factor involved in the development of obesity is an increase in the US food supply and portion sizes. The US food supply now provides 500 more calories per day per capita compared to the 1970s.[15] In addition, package sizes of food sold in stores and the size of restaurant, fast food, and home-cooked meals have all increased.[16,17] On average, food portion sizes are 2-5 times larger than they were twenty years ago.[18] These larger sizes not only contain more calories, but they influence people to eat more than they might otherwise; people tend to consume 18-45% more at meals or when snacking when served larger portion sizes.[17] This increase in consumption directly affects obesity prevalence as it leads to an increase in energy intake and contributes to positive energy balance.

Many other societal and environmental factors also influence the risk of obesity. For example, increased exposure to food advertising may increase energy intake.[19] Technological advances that decrease physical labor combined with longer work schedules and commutes may make people more sedentary. Furthermore, access to healthy food and supermarkets can also play a role in the prevalence of obesity, which will be discussed later.

Personal Factors. Personal factors that may contribute to the risk of obesity start at the genetic level. Monogenetic mutations, such as leptin and leptin receptor deficiencies, account for a small percentage of those with obesity. However, most commonly, obesity is the result of polygenic inheritance.

Research on families, parent-offspring relationships, and twins report the genetic contribution to body weight to be about 40-70%.[20] This genetic susceptibility to obesity is coupled with a variable load of environmental factors to determine an individual's risk of obesity.

Another personal factor that may contribute to obesity risk is medications that an individual may be taking. Medications that may increase the risk of obesity include a number of antidepressants (e.g. fluoxetine, paroxetine, and sertraline), some anti-seizure medications (e.g. valproic acid), some diabetes medications (e.g. glimepiride, glipizide, and insulin), some antipsychotic medications (e.g. clozapine, lithium, and risperidone), and steroids (e.g. methylprednisolone and prednisone).[21]

Ultimately, obesity occurs when energy intake exceeds energy expenditure. There are two factors directly related to energy intake and expenditure that are associated with the rise of obesity rates over recent decades. The first is an increase in sedentary behavior.[22] About one-fourth of US adults report that they do not engage in any leisure-time physical activity.[23] The second factor is changes in diet and consumption of energy-dense foods, which may increase total energy intake.[22,24] Age, pregnancy, lack of sleep, stress, emotional factors, low socioeconomic status, and food insecurity have also been proposed as contributors to obesity risk, some of which will be discussed later.

Treatment of Obesity

Because of the increased morbidity, mortality, and healthcare costs associated with obesity, treatment is recommended. The main aim of treatment is to improve the health of the patient through prevention or treatment of weight-related complications by weight loss.[10] Sustained weight loss of only 3 to 5% of body weight has been shown to provide positive health benefits, including reductions in triglyceride and blood glucose levels and a lower risk of type 2

diabetes.[25] Greater amounts of weight loss can decrease blood pressure, improve lipid levels, and reduce the need for certain medications.[25] Weight-loss goals are individualized based on comorbidities and complications, but a usual goal is around 10% of body weight.[10]

Behavior and Lifestyle Interventions. Usually, the first method used to induce weight loss for those with obesity is behavior and lifestyle interventions. These interventions focus on behavior and reinforce positive changes in diet and physical activity level.[8,22] The main component of many of these interventions is reducing total caloric intake, often through modification of macronutrient composition of the diet.[10] Aerobic physical activity and resistance training are also typically included in these interventions when feasible.[10] Aerobic activity can be progressively increased in amount and intensity throughout the intervention up to about 150 minutes per week as tolerated, divided into 3 to 5 sessions.[10] Resistance training is prescribed to promote fat loss while maintaining fat-free mass.[10] Adherence to recommendations is aided by behavioral interventions, such as self-monitoring food intake, physical activity, and weight; education; goal-setting; problem-solving; stress reduction; cognitive behavioral therapy; motivational interviewing; and counseling.[10,25] These interventions should be personalized to ethnic, cultural, socioeconomic, and educational backgrounds.[10] It is recommended that behavior and lifestyle interventions be followed by a comprehensive weight maintenance program lasting one year or longer.[8] Behavioral interventions have been shown to be effective for weight loss and reduction in cardiovascular disease risk through clinical trials such as the Diabetes Prevention Program and Action for Health in Diabetes (Look AHEAD).[22]

Pharmacotherapy. Pharmacotherapy is usually used in conjunction with behavior and lifestyle interventions in those who have difficulty losing weight or those in need of a more aggressive weight loss plan, who have weight-related comorbidities that can be improved by weight loss.[10,26] There are a number of

Food and Drug Administration (FDA)-approved drug options available for obesity treatment, including phentermine, orlistat, lorcaserin, phentermine/topiramate, naltrexone/bupropion, and liraglutide. The medication used depends on the comorbidities and characteristics of the patient.[10] Phentermine has been in use since 1959 and is the most commonly prescribed medication for obesity treatment.[27,28] It stimulates the synaptic release of norepinephrine, dopamine, and serotonin in the brain and decreases food intake by suppressing appetite.[27] Orlistat was approved by the FDA in 1999.[27,29] It is a lipase inhibitor that causes dietary fat to be excreted instead of absorbed.[26] Lorcaserin and combination phentermine/topiramate were both approved for obesity treatment by the FDA in 2012.[29] Lorcaserin antagonizes the serotonin 2c receptor in the hypothalamus and decreases food intake through increased feelings of satiety.[26,30] Topiramate has unclear mechanisms but is thought to reduce food intake, suppress appetite, and alter satiety through modulation of GABA receptors in the brain.[27,28,31] Naltrexone/bupropion and liraglutide are the most recently approved FDA anti-obesity medications; both were approved in 2014.[29] Naltrexone is an opioid receptor antagonist and bupropion is a dopamine and norepinephrine reuptake inhibitor.[32] The combination is thought to induce weight loss through potentiation of proopiomelanocortin (POMC) neuronal activity in the hypothalamus, with effects on appetitive and reward pathways in the brain.[32] Liraglutide is a glucagon-like peptide-1 (GLP-1) receptor agonist that delays gastric emptying, increases satiety, and decreases food intake.[33]

Bariatric Surgery. Different bariatric surgical procedures have been developed to aid in the treatment of obesity. They are typically recommended for those with a BMI greater than or equal to 40 kg/m^2 without complications or those with a BMI greater than or equal to 35 kg/m^2 with one or more severe obesity-related complications and those that have not responded to behavioral and medical interventions.[8,10] However, the risk and timing of undergoing a bariatric

surgical procedure also needs to be carefully considered.[10] The main types of bariatric surgery are restrictive and restrictive and malabsorptive.

Restrictive bariatric surgery decreases the amount of food that can be consumed; variations include gastric banding and sleeve gastrectomy. Gastric banding involves placement of an inflatable band around the top of the stomach to create a smaller stomach pouch; it does not permanently alter the gastrointestinal tract.[26] Sleeve gastrectomy, on the other hand, permanently alters the stomach anatomy by removal of a portion of the stomach, leaving a tube-shaped sleeve.[26]

Restrictive and malabsorptive bariatric surgery procedures decrease the amount of food that can be absorbed, in addition to decreasing the amount that can be consumed. These procedures include Roux-en-Y gastric bypass and biliopancreatic diversion with duodenal switch (BPD/DS). With the gastric bypass procedure, a small pouch is created at the top of the stomach, and the jejunum of the small intestine is attached through a small hole in the pouch.[26] This structure allows food to bypass part of the stomach and intestine, reducing absoprtion.[26] In BPD/DS, part of the stomach is removed, and the distal part of the small intestine is attached to the stomach.[34] The part of the small intestine that was bypassed is reconnected to the last portion of the small intestine so bile and pancreatic enzymes can mix with the food stream, but with a relatively short common channel for mixing nutrients with digestive enzymes.[34]

Given the nature of these procedures, BPD/DS has been found to result in the most weight loss, followed by Roux-en-Y gastric bypass, and finally, gastric banding.[35] However, BPD/DS has a higher complication rate and risk of mortality than the other procedures.[36] BPD/DS is more likely to cause protein, vitamin, and mineral deficiencies, as well.[36] Roux-en-Y gastric bypass, on the other hand, results in significant weight loss but is a more complex operation than either

gastric banding or sleeve gastrectomy.[36] However, the best procedure depends on the individual characteristics of the patient.

Frequently, multiple types of therapy will be utilized together to develop more individualized treatment plans to help optimize chances of success for difficult to treat individuals. Unfortunately and paradoxically, those with food insecurity may be at particular risk for obesity and may be harder to reach effectively with treatments. In this next section, food insecurity will be addressed in detail.

Food Insecurity

Food insecurity occurs when access to nutritionally adequate and safe foods, or the ability to acquire these foods in socially acceptable ways, is limited by a lack of money or other resources.[37,38] Since food insecurity is usually assessed by self-report on questionnaires, it can be difficult to determine if individuals with reported food insecurity have an actual decrease in energy intake or just fear of such happening. Regardless, people with food insecurity tend to report worrying about running out of food, not being able to afford balanced meals, and reduced meal size or skipping meals.[37] Food insecurity is typically experienced in an episodic nature. Episodes of food insecurity are usually short in duration, but households often experience repeated episodes.[37] Of US households that experienced food insecurity during some part of 2015, food insecurity was experienced in 7 months of the year on average.[37]

The US Department of Agriculture (USDA) Economic Research Service (ERS) conducts an annual, nationally representative survey to determine food insecurity in the US.[37] Using the 18-question US Food Security Module (Table 1), households are classified as food secure (up to two food-insecure conditions), low food security (three to five food-insecure conditions or three to seven for households with children), or very low food security (six or more food-insecure

conditions or eight or more for households with children).[37] Although food insecurity, defined as low food security or very low food security in this survey, is down from a high of 14.9% of households in 2011 to 12.7% in 2015, the current prevalence of food insecurity is still greater than the 2007 prerecession level of 11.1%.[37] For 2015, this equates to 15.8 million households with food insecurity and 42.2 million people living in these food-insecure households.[37] In addition, 5% of US households, about 6.3 million, are considered to have very low food security.[37] At this level of food insecurity, some members of the household experience both reduced food intake and disrupted eating patterns.[37]

Table 1. Food Security Assessment

US Food Security Module Questions

1. "We worried whether our food would run out before we got money to buy more." Was that often, sometimes, or never true for you in the last 12 months?
2. "The food that we bought just didn't last and we didn't have money to get more." Was that often, sometimes, or never true for you in the last 12 months?
3. "We couldn't afford to eat balanced meals." Was that often, sometimes, or never true for you in the last 12 months?
4. In the last 12 months, did you or other adults in the household ever cut the size of your meals or skip meals because there wasn't enough money for food?
5. (If yes to question 4) How often did this happen—almost every month, some months but not every month, or in only 1 or 2 months?
6. In the last 12 months, did you ever eat less than you felt you should because there wasn't enough money for food?
7. In the last 12 months, were you ever hungry, but didn't eat, because there wasn't enough money for food?
8. In the last 12 months, did you lose weight because there wasn't enough money for food?
9. In the last 12 months did you or other adults in your household ever not eat for a whole day because there wasn't enough money for food?
10. (If yes to question 9) How often did this happen—almost every month, some months but not every month, or in only 1 or 2 months?

Questions 11-18: only for households including children age 0-17

11. "We relied on only a few kinds of low-cost food to feed our children because we were running out of money to buy food." Was that often, sometimes, or never true for you in the last 12 months?
12. "We couldn't feed our children a balanced meal, because we couldn't afford that." Was that often, sometimes, or never true for you in the last 12 months?
13. "The children were not eating enough because we just couldn't afford enough food." Was that often, sometimes, or never true for you in the last 12 months?
14. In the last 12 months, did you ever cut the size of any of the children's meals because there wasn't enough money for food?
15. In the last 12 months, were the children ever hungry but you just couldn't afford more food?
16. In the last 12 months, did any of the children ever skip a meal because there wasn't enough money for food?
17. (If yes to question 16) How often did this happen—almost every month, some months but not every month, or in only 1 or 2 months?
18. In the last 12 months, did any of the children ever not eat for a whole day because there wasn't enough money for food?

Epidemiology

Much data about the demographic characteristics of those with food insecurity has come from the USDA ERS or the National Health and Nutrition Examination Survey (NHANES), a cross-sectional survey administered by the National Center for Health Statistics.[39] NHANES is representative of the civilian, noninstitutionalized US population and collects data on demographics, dietary intake, mental health, and behavior.[39] Using this research, it has been found that those with food insecurity tend to have differences in household composition and size, sex, race/ethnicity, age, education, insurance coverage, tobacco use, and location compared to those with food security.

The USDA ERS found that households with incomes near or below the federal poverty line had much higher rates of food insecurity.[37] Loopstra and

Tarasuk conducted a longitudinal research study and found that changes in income and level of food security were closely associated, with increases in income leading to improvements in food security and decreases leading to worsening food security.[40] In addition, a change in the number of household members with employment was associated with changes in food security.[40]

Household composition and size also play a role in the risk of food insecurity. An association has been found between food insecurity and marital status. Separated and divorced individuals have the highest rates of food insecurity, but single people living alone are also at risk.[37,41] Also, larger households, specifically households with four or more people, are at an increased risk for food insecurity.[42] This relationship may be because some of the individuals within larger households are not employed or contributing to income but still need to be fed, such as children. US Households with children have a higher rate of food insecurity, 16.6% of households, compared to the national average, which is 12.7% of households.[37] However, when households with children contain a married couple, the rate of food insecurity drops to 10.2% of households.[37] Households with children that are headed by a single woman (30.3% food-insecure) or single man (22.4% food-insecure) are more likely to be food insecure compared to other households.[37] Although, in about half of food-insecure households with children, only the adults in the household were actually considered food insecure, with older children more likely to see the effects of food insecurity compared to younger children.[37]

In addition to income and household composition, sex also has a role in food insecurity. In general, women are more likely to report living in a food-insecure household compared to men, for both non-married and married respondents.[37,43,44] However, Matheson and McIntyre found that after adjusting for household characteristics, the relationship to food insecurity among non-married female respondents was no longer statistically significant.[43] This

suggests that higher rates of food insecurity in non-married women are likely due to economic and demographic characteristics, such as lower household incomes and living in larger households with more children.[43] On the other hand, the relationship between married women and food insecurity remained statistically significant after adjusting for household characteristics.[43] Matheson and McIntyre suggested that this was due to women having greater sensitivity to the needs of the household compared to men.[43] Men and women in a household may also have different information on the food security of the household, as women are more likely to take care of household budgeting and food purchases.[43,45] This could also be because women may prioritize other's needs over their own and end up skipping meals, waiting to eat until later in the day, or eating less overall.[43,46]

A few other demographic characteristics are also associated with food security status. Investigators, using data from NHANES, found that African Americans were two and a half times more likely to be food insecure, while among Hispanics that number was four times.[42] Age has also been found to be associated with food security status, with younger adults more at risk for food insecurity.[42] Food insecurity has been associated with less education and lack of health insurance.[42,47,48] Finally, tobacco smokers have been found to be three times more likely to be food insecure compared to those that do not smoke.[42] This means that despite not having enough to eat, individuals with food insecurity are spending a portion of their limited income on tobacco products. This increase in tobacco use among those with food insecurity could be because of the addictive nature of tobacco or inadequate access to smoking cessation programs.[42]

Lastly, households with food insecurity are not distributed evenly across the US. Rates of food insecurity were found to be higher in the southern US compared to the Northeast or West, while the Midwest, with a level between the

other regions of the country, was not significantly different from any other area.[37] Food insecurity was highest among households located in rural areas and lowest for those in the suburbs.[37] Overall, each individual with food insecurity faces different challenges, some of which may contribute to the risk of obesity.

Food and Nutrition Assistance Programs

There are a number of programs in place aiming to help individuals experiencing food insecurity. In this section, the Supplemental Nutrition Assistance Program (SNAP), the largest of 15 federal nutrition assistance programs, will be discussed.[39] SNAP, formerly the Food Stamp Program (FSP), currently serves 1 in 7 Americans.[39] It provides monthly benefits to low-income households (at or below 130% of the federal poverty level) to purchase food.[37] Within a yearlong period, approximately 42% of low-income adults received SNAP benefits.[39] Benefits are provided through electronic benefit cards and are used to buy food at authorized retailers.[49] The average SNAP benefit is about $127 per person per month.[37]

Those who participate in federal nutrition assistance programs are different from those who do not in a couple of ways. SNAP/FSP participants are more likely to live in larger households, have lower education, be single with children, receive other forms of social assistance, and be female compared to those who do not participate.[50] About a third of households that are eligible for SNAP benefits do not participate.[49] The two largest barriers to using food and nutrition assistance programs appear to be fear of stigma associated with such programs and limited knowledge about the types of benefits that are available.[50] Another barrier to participation is the application process. The SNAP application can include intimidating language and has been found to have an average length of 12 pages.[51] Bhattarai et al. found that the length of the application, which varies by state, was negatively correlated with participation.[50] In addition, the

application process can include many visits to government offices during normal working hours.[51]

Though it could certainly be more effective in reaching those in need, SNAP has been somewhat effective; there is evidence that SNAP does reduce food insecurity by 20-50%.[39,49,52] As expected, this effect is stronger for those receiving larger SNAP benefits.[49] However, this reduction in food insecurity does not take into consideration the types of foods that are being consumed and the psychological effects of alternating periods of abundance and scarcity that this program can produce. These will both be discussed in more detail later.

Risk of Chronic Disease

Despite attempts to put programs in place to help those with food insecurity, it is still an issue for many households in the US. This is of concern as food insecurity may increase the risk of negative health consequences. Those with food insecurity have been found to have a higher risk of chronic diseases, including obesity,[53] diabetes,[47] hypertension,[47,54] and cardiovascular disease[42] compared to those with food security. Additionally, compared to those with food security, those with food insecurity have been found to have 1.65-fold increased odds of metabolic syndrome, defined as three or more of the following: increased waist circumference, increased triglycerides, decreased high-density lipoprotein cholesterol (HDL-c), elevated blood pressure, or increased blood glucose.[55] Metabolic syndrome is associated with increased risk for both diabetes and cardiovascular disease.[55] Furthermore, those with food insecurity are more likely to report fair or poor health on surveys and score lower on physical and mental health scales compared to those with food security.[56]

Food insecurity and financial hardship may increase the risk of chronic disease by making it difficult to afford prescription medications, therefore making it more difficult to self-manage health conditions.[47] Among those with a chronic

disease, 55.5% of those with food insecurity reported cost-related medication underuse, compared to 16% of those with food security.[57] Those with food insecurity also report delays in filling prescriptions.[58,59] Ultimately, a lack of resources may force individuals to decide between food and medications, and many people may prioritize basic needs over health care.[59] Researchers have found that those who prioritize food over medications have increased visits to emergency departments.[60] This may be why food insecurity itself is also associated with overall increased acute care utilization and increased hospitalizations.[59] Increased health care costs could play a role in the development and worsening of food insecurity as well, as the out-of-pocket costs associated with health care could mean less money available for food.[47] In these next sections, the relationship between food insecurity and some specific health conditions will be examined.

Cardiovascular Disease. Differences in food security status have been found to correlate with differences in cardiovascular health. Those with food insecurity may have a higher risk of cardiovascular disease compared to those with food security.[42] In addition, in one study, adults from food-insecure households had a 21% higher risk of hypertension, defined as high systolic blood pressure (SBP), high diastolic blood pressure (DBP), or antihypertensive medication use, compared to those from food-secure households.[47] In another study, food insecurity remained associated with hypertension even after adjusting for socioeconomic position (level of education and relationship to the federal poverty level) and other confounders (age, sex, race/ethnicity, health insurance coverage, marital status, and current smoking status), meaning that food security itself played a major role in this relationship.[54] In other research, it was found that older adults with food insecurity are at a higher risk of peripheral artery disease (PAD), which consists of arterial blockages that compromise blood flow to the

abdominal aorta and arteries of the lower extremities.[61] Those with PAD are at a higher risk of stroke, myocardial infarction, and lower extremity amputations.[61]

Diabetes. Unfortunately, there is also a link between food insecurity and diabetes risk. The risk of diabetes, assessed by high fasting plasma glucose, insulin use, or oral hypoglycemic medication use, has been shown to be about 50% higher for those living in food-insecure households compared to those living in food-secure households.[47] In addition, in those who have diabetes, there are a number of ways that food insecurity can complicate glycemic control and other aspects of diabetes self-management.

For those who have diabetes, food insecurity can make the disease more difficult to manage. Food insecurity may cause intake to vary considerably based on food availability, leading to unpredictable blood glucose values, complicating medication and insulin regimens.[62] In several studies, those with food insecurity have been found to be less likely to have adequate glycemic control of their diabetes (measured as HbA_{1C} > 9%) compared to those with food security.[47,62,63] Those with low incomes (and more likely to be food insecure) may also have a higher rate of hospital admissions due to hypoglycemia compared to those with high incomes.[64] These hospital admissions were 27% more likely to occur in the last week of the month compared to the first week.[64] Hypoglycemia can result when hypoglycemic medication doses are kept stable, but food intake is reduced. These higher rates of hospital admissions in the last week of the month could be due to food budgets being exhausted at the end of the month. Furthermore, those with food insecurity may be less likely to afford the supplies needed for successful management of their diabetes, such as blood glucose meters.[62] Those with diabetes and food insecurity report a high frequency of either delaying purchase of testing supplies and medication or postponing food purchases.[62] In addition, those with food insecurity may have diets high in foods that patients with diabetes are counseled to avoid, such as refined

carbohydrates, added sugars, and added fats, which can further complicate management.[62] Because of these factors or others not mentioned here, those with diabetes and food insecurity report lower self-efficacy, poorer adherence to blood glucose monitoring, and more hypoglycemia-related emergency department visits compared to food-secure individuals.[62]

Risk of Mental Health Conditions

In addition to chronic physical illnesses, those with food insecurity also have higher rates of a number of mental health conditions compared to those with food security.[65] Individuals with food insecurity have higher rates of depression,[66,67] anxiety,[67] stress,[67] irritability,[65] and social isolation[65] compared to the those with food security. Similarly, food-insecure households are more likely to be headed by a mother with depression, a psychosis spectrum disorder, or a history of domestic violence.[68] Furthermore, level of food insecurity may be correlated with mental health. Those reporting food insecurity with hunger have a higher prevalence of mental illness compared to those reporting food insecurity without hunger.[65] Hunger-associated mental illness is more likely in households headed by women or single parents, compared to other households.[65]

Food insecurity could be linked with mental health problems in various ways. Those with very low food security have much higher odds of social isolation, which is related to depression, stress, anxiety, and exposure to violence, abuse, and neglect.[69,70] In pregnant women, food insecurity has been found to be associated with a stronger belief that chance affects one's life and lower reports of self-esteem and mastery.[67] Similarly, the association between food insecurity and mental health problems could be due to the effects of exposure to violence; history of abuse; or stress, worry, and anxiety over not having enough money or food to feed oneself or family.[70] In addition, mental health conditions could lead to food insecurity. Examples include mothers with

depression, who may lack the energy to get groceries or cook for their families and mothers with psychotic symptoms, who may find it difficult to plan meals or manage finances.[68]

Depression. Depression is the mental illness that has been researched the most in relation to food insecurity. Adults reporting very low food security have three-fold higher odds of depression compared to adults with food security.[39] The depressive symptoms reported most frequently among adults with low and very low food security are feeling tired or having little energy; trouble sleeping or sleeping too much; and feeling down, depressed, hopeless.[39] As food insecurity worsens, the frequency of these symptoms has been found to increase.[39] Similarly, in one study conducted in Canada, it was found that those with moderate food insecurity were 32% more likely to report suicidal ideation compared to those with food security.[71] Among those with severe food insecurity, that percentage increased to 77%.[71] It is interesting to note that SNAP participants were found to have higher rates of depression at all levels of food security, except for very low food security, compared to non-participants.[39] It is possible that this is due to a potential stigma or feeling of dependency that the program may evoke.[39]

The association between food insecurity and depression has been found to be bidirectional in longitudinal research.[68,72] Food insecurity may disproportionally affect those with mental health problems, but it might play a role in the development of mental disorders as well.[71] One way that food insecurity may lead to depression is through exposure to stress from worry about having enough food or the experience of actually not having enough food.[72]

Anxiety. Laraia et al. found that women from food-insecure households were more likely to report anxiety, as assessed by Spielberger's Trait Anxiety Inventory, than those from marginally food-secure households and food-secure households.[67] They also found that as anxiety symptoms increased, household

food security status worsened.[67] The association between food insecurity and anxiety has also been seen using the WHO Composite International Diagnostic Interview-Short Form (CIDI-SF) to test for generalized anxiety disorder[73] and when subjects are asked if they have been diagnosed with an anxiety disorder by a health professional.[65] There are a number of ways in which food insecurity may contribute to anxiety symptoms. Food insecurity may induce feelings of anxiety over whether there will be enough food to feed oneself or family in the near future.[74] For those at the lowest levels of food security, needing to resort to socially unacceptable ways to acquire food may cause additional anxiety.[75] Finally, exposure to violence, which is associated with food insecurity, may also lead to increased anxiety.[76] This topic will be discussed next.

History of Exposure to Violence. One way that mental health and food insecurity problems may be linked is through exposure to violence, as those with food insecurity tend to report higher exposure to violence.[70] This violence includes exposure to rape and sexual assault, child abuse and neglect, becoming a perpetrator of violence, and attempted suicide or suicidal ideation.[70] In one study, over half of the participants who reported very low food security also reported violence that had a life-changing impact.[70] Domestic violence, for example, could cause women to feel a sense of loss of control and to be preoccupied with fear.[68] Sexual assault has been linked to the inability to maintain a steady job, complete education, and develop healthy relationships.[70] Those reporting sexual assault noted that it had a large impact on their current financial situation, including inability to afford enough food.[70] Possibly because of these effects, Wehler et al. found that among homeless and low-income mothers, those with experience of sexual assault were four times more likely to report food insecurity compared to women who had not been assaulted.[77] In addition, those with very low food security report more violence during childhood.[70,77] There are many ways abuse in childhood could lead to mental health problems. Among

these is that child abuse can involve withholding of food or other abuse activities involving food, which can distort an individual's relationship with food.[70]

In addition to being victims of violence, those with food insecurity are also more likely to report being perpetrators of violence themselves compared to those with food security.[70] Violence towards others and suicidal ideation are normal reactions to stressful situations, according to trauma theory.[70] These types of experiences can lead individuals down paths eventually resulting in not having enough money for food or other basic needs.[70]

Access to Mental Health Care. Unfortunately, access to mental health care may be more difficult for individuals with food insecurity. Among a sample of African-American women visiting a food pantry, only a few women stated that they have access to mental health professionals, while others indicated that they have had a difficult time accessing providers in the mental health care system.[76] Many of these women also did not believe that a mental health professional could treat their depression.[76] In addition, some women even expressed disdain for mental health practitioners.[76] Overall, this complicated relationship between food-insecure individuals with mental health problems and mental health providers may make receiving help and treatment particularly challenging for this population.

Food Insecurity May Contribute to a Higher Risk of Obesity

Though it may seem contradictory, a number of investigators have found a significant positive correlation between food insecurity and overweight and obesity, in what is commonly referred to as the hunger-obesity paradox, which is the focus of this project.[38,78–81] Nettle et al. conducted a large meta-analysis and found that those with food insecurity had a 21% higher odds of having a high body weight compared to individuals with food security.[81] This association was stronger in women than in men.[81] When these results were adjusted for

publication bias (the theory that significant positive associations are more likely to be published), the results remained significant.[81]

The association between food insecurity and overweight and obesity varies when food security status is broken into different levels. Studies on the association between food insecurity and obesity are difficult to compare due to the various definitions and assessments of food security that are used. Nevertheless, Wilde and Peterman found that when broken down into different levels of food security, determined using the U.S. Food Security Module, obesity prevalence formed a U-shaped curve.[82] In women, those reporting marginal food security and food insecurity without hunger had significantly higher rates of obesity compared to individuals with food security.[80,82] Regarding men, those with marginal food security had a higher rate of obesity, but more extreme levels of food insecurity were related to lower rates of obesity.[82] Similarly, both underweight and overweight individuals have been found to be more likely to report food insecurity, in data from NHANES.[42] Furthermore, Wilde and Peterman found that rates of weight gain over a 12 month period were highest for women from households with intermediate food security.[82]

It is possible that the data linking food insecurity with obesity is due to a common third variable, such as income or socioeconomic status.[81] However, in one meta-analysis looking at various studies of food insecurity and body weight, it was found that the analyses that controlled for socioeconomic factors did not show substantially weaker estimated associations.[81] Therefore, food insecurity may be a marker for additional non-socioeconomic factors which contribute to obesity risk. There are a number of differences between those with food insecurity and those with food security that may contribute to these populations' different rates of obesity. This section will focus on differences in eating patterns, nutritional quality of the diet, access to food, cost of food, food and nutrition

assistance programs, and access to health care. In addition, stress-related pathophysiology will be examined as a possible risk factor for obesity.

Eating Patterns and Behaviors

Meals consumed in a day, snacking, and disordered eating patterns differ between levels of food security. Their role in the relationship between food insecurity and obesity will be discussed here.

Those with food insecurity report consuming fewer meals compared to individuals with food security.[83] This could be because those with food insecurity may have less time available for meals or because they may not have the resources for a full meal and have to rely on snacks instead. Even though those with food insecurity consume fewer meals, the energy contributed by each meal and the energy contributed by snacks is higher for the population with food insecurity.[83] This could lead to a higher daily energy intake, possibly resulting in an increased risk for obesity.

Snacking could play a role in the relationship between food insecurity and obesity because, as stated previously, total energy contributed by snacks is higher for those with food insecurity compared to those with food security.[83] Snacks have been found to have no impact on the time to the next meal, hunger ratings, and energy intake at the next meal, which could lead to higher energy intake overall.[84] In one study, investigators found that there was only a slightly increased plasma glucose after consumption of a snack, but that the snack led to an additional acute rise in insulin and suppression of the typical postprandial rise in free fatty acids (FFA) in the following 2 hours.[84] This usual increase in FFA has been hypothesized to spare glucose, leaving more glucose available for satiety signaling in the brain.[84] By suppressing this natural increase in FFA, these investigators hypothesized that snacking could decrease the amount of glucose available for the brain, subsequently triggering feelings of hunger sooner.

Potentially, an increase in snacking, especially of snacks high in carbohydrates, among those with food insecurity, and the subsequent increase in hunger and further consumption of typical snack foods could lead to a vicious cycle, increasing this population's risk of obesity.

Not surprisingly, individuals with food insecurity may be at a greater risk for disordered eating. Some of these patterns could predispose these individuals to weight gain and obesity. Women with food insecurity during pregnancy or postpartum reported higher levels of disordered eating behaviors compared to those with food security.[85] This was assessed by the Eating Attitude Test (EAT), which includes questions about avoidant food behaviors, binge eating, dieting, guilt about eating, preoccupation with food and weight, and vomiting.[85] In addition, a significant correlation was found between food insecurity and disordered eating patterns among rural women, based on questions from the Stanford Eating Disorders Questionnaire.[86] Other investigators found that women from food-insecure households were more likely to report emotional eating, defined as eating when upset, eating for comfort, eating when not hungry, and eating until the package of food was finished, than those from food-secure households.[87] However, more research is needed on specific eating behaviors, prevalence of these behaviors, and these behaviors in men.

Nutritional Intake and Diet Quality

In addition to different eating patterns and behaviors, populations with food insecurity have been found to have different nutrient intakes and diet quality compared to those with food security. Based on NHANES data, it was found that lower food security was associated with higher intakes of high-fat dairy products, which are considered highly palatable foods.[88] Also, those reporting very low food security consumed 12% more sugar-sweetened beverages (SSB) and 5% more red and processed meat servings compared to individuals with food

security.[88] Investigators have also found that people with food insecurity have a lower consumption of fruit and vegetables and a higher total fat and saturated fat intake.[48,86,88] Overall diet quality, when assessed by the Healthy Eating Index (HEI), is lower among those with food insecurity compared to those with food security, even after adjusting for sociodemographic characteristics and total energy intake.[79,88] Diets that are high in processed meats and SSB and low in fruits and vegetables are associated with inflammation and weight gain.[89,90] Likewise, the high level of SSB consumed by this population makes them especially prone to weight gain, type 2 diabetes, and cardiovascular disease.[91] Dietary patterns such as these among those with food insecurity may be one reason this population has a higher prevalence of obesity. Differences in diet between those with food insecurity and those with food security could be due to access to food, the cost of different foods, food and nutrition assistance programs, or stress, each of which will be discussed next.

Food Access

Another factor that may link food insecurity and obesity is a lack of access to healthy food. Many individuals with food insecurity live in areas considered food deserts. Researchers use the term “food desert” differently, but it typically refers to an area without a supermarket, as supermarkets tend to offer customers food of better quality, variety, and price compared to smaller grocery and convenience stores.[92] Low-income areas have nearly 30% fewer supermarkets and tend to have more fast food restaurants and corner stores compared to high-income areas.[93] Though supermarkets may not be too far outside of low-income areas, low-income individuals report difficulty accessing and affording transportation to supermarkets outside their community.[93,94] This often results in people making food choices based on the options that are available in their neighborhood, which can be a problem for low-income individuals as smaller

grocery and convenience stores may have limited healthy options and higher prices.[95]

There are a number of differences between supermarkets and smaller grocery, corner, and convenience stores that may contribute to obesity in those that only have access to smaller stores. The smaller stores in low-income neighborhoods usually have a smaller quantity of food products and less variety compared to supermarkets.[93] Small grocery stores in urban areas have been found to have limited fruit and vegetable choices.[93] When fresh fruits and vegetables are available, stores typically only have one or two pieces of each type that they carry and these items are usually of poor quality, if not inedible.[93] Smaller stores in low-income areas are also less likely to have other healthy options, such as whole wheat bread and grain products, ground beef with ≤ 10% fat, and low-fat cheeses.[96] When healthy options are limited or unavailable, individuals may consume less of these products. Rose and Richards found that difficult access to a supermarket and larger distances from home to a supermarket were associated with decreased household use of fruits,[94] but this result has not been seen in similar research.[97]

Another difference between supermarkets and smaller stores that could play a role in the development of obesity is that smaller grocery and convenience stores tend to have higher prices. Smaller grocery stores tend to stock leading brand items and items with smaller package sizes, which can bring prices up.[92] Theft from stores in low-income areas can also drive prices up.[92,93] This results in households with the lowest incomes paying more for the same foods compared to households with higher incomes, making it even harder to achieve a healthy diet.[93,98] Overall, with the barriers involved in living in a food desert, it is not surprising that those with limited access to supermarkets have a higher prevalence of overweight and obesity[97,99,100] and that moving from a non-food

desert to a food desert increases the odds of an individual being overweight by 19% and obese by 30%.[101]

Food Cost

Those with low incomes report economic factors as the main barrier to eating healthier diets.[102] It has been found that the proportion of income spent on food by those in poverty (more than 25% of income) is much higher compared to the average proportion of income spent on food in the US (11% of income).[103] This is likely because as income increases, the amount of money dedicated to food also tends to increase, but the proportion of income spent on food decreases.[102] Despite a greater proportion of their income going to food, those in food-insecure households tend to spend less money on food and spend less per calorie.[102]

Smaller food budgets may translate into a reduced ability to buy healthy options, as healthier options tend to be more expensive than other choices, regardless of where they are purchased.[96] This is particularly the case for whole wheat breads and grains, low-fat ground meats, and skinless poultry.[96] When it comes to whole grains, one reason healthier options are more expensive is that whole grains tend to come in smaller packages than standard items, which increases their price per unit.[96] For ground meats, price increases as the fat content decreases, resulting in low-income populations purchasing fattier cuts.[96,102] Furthermore, foods that have high energy density (defined as energy per unit of weight), such as fats, oils, added sugars, and refined grains, provide more calories at a lower cost.[102,103] On the other hand, foods with a low energy density, such as lean meats, fish, vegetables, and fruits, are more expensive regarding cost per calorie.[102,103] Differences in price result in the fact that as diet quality increases, so does the estimated amount spent on food each day.[104] In addition, higher costs are associated with greater dietary diversity and nutrient-

based scores.[102] In contrast, higher consumption of added sugars and fats is associated with lower dietary costs.[102]

There are a number of reasons why those with food insecurity may purchase unhealthy, energy-dense foods. First, and most obvious, is that low-income and food-insecure individuals may not have the money to purchase more expensive, healthier foods. It has been shown that the higher prices for healthier options can increase the cost of food for a low-income, family of four about $850 to $960, or about 35% to 40% of their food budget, which is not feasible for many.[96] In addition, those with low incomes and food insecurity may seek out foods that provide more calories per dollar, which are typically energy-dense, unhealthy foods, as mentioned previously.[38,42] It has been found that price influences food choices much more than labels stating that food is healthy, especially for those with low incomes.[102,105] The way price influences food choices can be seen in a large meta-analysis of studies on those participating in food assistance programs and the general population.[106] It was found that that a 10% decrease in price increased consumption of healthy foods by 12% while a 10% increase in price decreased consumption of unhealthy food by 6%.[106]

In addition to being cheaper, unhealthy foods are considered easier to find and prepare; they may also be more likely to be preferred by children.[102] Furthermore, low-income families may be reluctant to try new (and possibly healthier) foods because of the risk for food waste, which can be a difficult situation for those in poverty.[102] This food waste could arise from either food needing to be thrown out because the family does not like it and will not eat it or from produce that goes bad before the family has a chance to eat it. Overall, there are many reasons why those with food insecurity may choose unhealthier food options, including access to food and cost of food, which results in poorer nutrition for this population. Many of these factors may place those with food

insecurity at a disproportionate risk for obesity compared to individuals with food security and those at higher income levels.

Food and Nutrition Assistance Programs

Another mechanism through which food insecurity and obesity have been linked is participation in food and nutrition assistance programs, such as SNAP and food pantries. It has been found that SNAP participants have larger waist circumferences and a 58% higher odds of obesity compared to SNAP nonparticipants.[80,107] However, results are mixed as to whether food assistance programs cause obesity or if those with obesity are more likely to participate.[107] Regardless, there are two ways that programs aiming to reduce food insecurity may play a role in the food insecurity and obesity relationship, by changing the foods that individuals consume and through the effects of the food stamp cycle.

Food and nutrition assistance programs may influence the risk of obesity by changing the types and amount of food eaten. Investigators have found that female SNAP participants consume more calories compared to female nonparticipants.[108] It has also found that participants in SNAP/FSP consume more added sugars and total fat because of participation.[109] Both of these could lead to positive energy balance and a higher risk of obesity. The research that has been done has found interesting results, but more research on this topic is needed.

Food pantries may also influence what individuals consume based on the foods that they offer. As would be expected, food pantries are used much more frequently by food-insecure households compared to food-secure households.[50] Those that use other types of social assistance are also more likely to use food pantries compared to those that do not use social assistance.[50] Although these organizations are usually set up to assist individuals temporarily, many clients rely on food pantries for extended periods of time, with a medium length of use of

2 years.[50,110] Some users of food pantries even report using multiple food pantries to meet their needs.[110]

Food pantries usually collect food donations from retailers, manufacturers, wholesalers, distributors, industries, producers, churches, and individuals in the community. They then either give eligible households predetermined bags of various food items or allow clients to shop though available food based on their needs.[50,110] There are significant limitations and variations in the types of food that food pantries can provide because they rely heavily on these donations. In addition, perishable foods are harder to distribute. Fruits and vegetables provided by food pantries are usually in the form of tomato sauce, canned fruits and vegetables, and juice.[110] Simmet et al. conducted a systematic review of research on food pantries and found only two out of nine studies in which the food provided by food pantries was adequate to meet the nutritional needs of clients over the number of days the food was intended for.[110] Because of this, those that use food pantries may not have a dietary intake that meets recommendations, which may play a role in obesity risk.[111]

Food and nutrition assistance programs may also contribute to obesity in those with food insecurity through the food stamp cycle. This term refers to overconsumption of food when SNAP or other benefits are first distributed followed by food restriction later in the cycle when those resources are depleted.[38] This most commonly occurs on a monthly cycle with three weeks of overeating, followed by a week of restriction, until the next month's benefits are received.[38] This cycle occurs because, on average, SNAP benefits are found to only last two to three weeks.[112] Effects of this were seen when servings of food consumed by participants over the course of a month was looked at; the number of servings significantly decreased in the last week of the month.[113] However, this effect may not be caused by food and nutrition assistance benefits alone, as many paychecks and other benefits may be distributed cyclically as well.[64]

Among low-income households, both with and without food assistance, food purchasing diaries and grocery store receipts have shown decreased consumption and spending at the end of the month.[64]

One mechanism through which the food stamp cycle may lead to obesity is called the insurance hypothesis, which is based on adaptive evolutionary theory.[81] This hypothesis states that the storage of body fat is an adaptive strategy long used by humans to protect themselves against periods where food may be unavailable.[81] However, this fat storage also has costs, such as increased energy requirements, health risks, and movement impairments.[81] The optimal storage of fat depends on access to food; when food is always available, it does not make sense to store fat and take on the associated costs.[81] Conversely, when there is a risk for temporary unavailability of food, the optimal level of fat storage increases to ensure survival through times of hardship.[81] Humans possess unconscious mechanisms that can increase or decrease energy intake to exceed, meet, or go below energy expenditure to reach optimal fat storage.[81] In this way, those with uncertain access to food, such as those receiving food assistance, may be prone to store excess body fat to prepare themselves for future hardships. Though the complete mechanisms through which this fat storage may occur are unclear, this hypothesis could be one explanation as to how food insecurity could lead to increased adiposity. Overall, food and nutrition assistance programs could affect the types of foods that individuals eat and create alternating periods of abundance and scarcity, possibly increasing obesity risk.

Other Factors

In addition to the factors mentioned above, there are a couple of other factors involved in the relationship between food insecurity and obesity that do not warrant an in-depth discussion in this thesis but are worth mentioning. One of

these is that the population with food insecurity may have limited knowledge about what is considered a healthy diet and how to live a healthy lifestyle.[94,114] This population may also have less confidence in their ability to consume a healthy diet, as women from food-insecure households were found to have lower scores on a scale to assess self-efficacy for healthy eating.[87]

Another factor is that those with food insecurity may have less time available for grocery shopping, food preparation, and physical activity.[94,114] Possible reasons for this include busy work schedules, working multiple jobs, and being a single parent. To et al. used accelerometry and questionnaires to assess physical activity and that found that those with food insecurity were less likely to meet the Physical Activity Guidelines for Americans, compared to those with food security.[115] Furthermore, those with food insecurity may have fewer opportunities for safe physical activity. This could be because they may live in unsafe neighborhoods (due to traffic or crime) or neighborhoods without sidewalks and they may not have access to a park, gym, or exercise facility.[11] Lastly, those with food insecurity report more sleep complaints, including a shorter duration of sleep among women, than those with food security.[116] This may be a contributing factor to obesity, but data are inconclusive.[117]

Stress

In the previous sections, a number of characteristics and external factors, which provide potential links between food insecurity and obesity, have been considered. Now, the potential impact of factors that promote obesity in the individual at behavioral and neuroendocrine levels through stress will be considered. Food insecurity has been found to be related to high levels of perceived overall life stress.[88] Stress is caused by events that are seen as physiologically or psychologically threatening, where an individual perceives the inability to cope with the event.[118] Stress can be caused by food insecurity itself,

as food insecurity can threaten survival.[88] Stress could also be brought about by various factors that play a role in food insecurity, such as unemployment or experiences of violence.[119] Stress may mediate the relationship between food insecurity and obesity through its impact on behavior and the neuroendocrine system, both of which will be discussed here.

Impact of Stress on Behavior

The impact of stress on behavior plays a role in energy balance by changing food preferences, changing the amount eaten, decreasing the time available for food preparation, and decreasing physical activity.[120] The two mechanisms that will be discussed here are how stress changes the quality and quantity of food eaten.

Investigators have found that during periods of stress, people sometimes consume less healthy diets with more convenience foods.[121] Under stress, consumption of fruits, vegetables, meat, and fish decreases and people tend to choose more pleasurable and palatable foods, such as highly caloric sweet and fatty snack foods.[119,121–123] Researchers found that all participants in one study, even those that reported decreasing their intake in response to stress, reported eating more sweets and chocolate when under stress.[123] When asked, subjects state that the reasons they choose these foods that they may normally avoid are because these foods make them feel better and that they taste good.[122] It has been proposed that the rewarding hedonic properties of these foods can reduce the discomfort caused by a stressful situation.[118,122]

One example of how stress influences intake is seen when cues that imply resource scarcity and environmental harshness, likely stress-inducing and experienced by individuals with food insecurity, make individuals more likely to choose and consume high-calorie foods.[124] Laran and Salerno studied passersby on a college campus and looked at perceived environmental harshness,

produced by posters with words associated with environmental harshness across from where participants were sitting, and M&M consumption.[124] It was found that perceived environmental harshness influenced participants to consume more M&Ms if they were told the M&Ms were high in calories but less if they were told the M&Ms were low in calories, compared to controls.[124] This result suggests that exposure to these cues increased the value of foods that can provide more energy.[124] On the other hand, the effect of environmental harshness was reduced when resources were provided to participants (in the form of monetary compensation).[124] This suggests that perceived environmental harshness did not simply influence taste, pleasure, or desire to indulge, but that it directly related to the availability of resources.[124] This study can be linked back to food insecurity because a perceived harsh environment coupled with a lack of resources could influence those with food insecurity to consume high-calorie foods.

Stress may also affect the quantity of food eaten. People tend to vary in their response to stress and the changes in intake that are reported vary by study. However, under stressful conditions, approximately 28-50% of people report increasing caloric intake, a small percentage report no change, and the rest report decreasing intake.[119,121,125] Women and overweight individuals are more likely to be among those who report overeating when stressed.[122,126,127] However, it is important to note that individuals' perceptions of amount of food consumed may not be reliable and that individuals tend to under-report food consumption in general; this unreliability may be a particular issue when stress is superimposed. Nevertheless, the amount that some individuals eat in stressful situations has been found to be much greater than the amount needed for homeostasis and to satisfy hunger.[128] This suggests that this food is not eaten for nutrition but rather because of its hedonic properties.[118] In this way, stress can increase intake above what an individual physically needs.

Impact of Stress on the Neuroendocrine System

Stress has been found to induce changes within the neuroendocrine system that could promote weight gain and obesity. Biologically, stress is defined as any factor that can overwhelm the body's ability to maintain homeostasis.[120] Acutely, the response to stress involves behavioral, autonomic, and endocrine changes that increase vigilance; increase heart rate and blood flow to the muscles, heart, and brain; and decrease appetite and food intake.[125] Short-term responses to stress are produced by the sympathetic nervous system (resulting in the fight or flight response). However, more long-term responses are modulated by other mechanisms, including the hypothalamic-pituitary-adrenal (HPA) axis.[119,125] The HPA response starts with corticotrophin-releasing hormone (CRH) from the hypothalamic paraventricular nucleus in the brain.[125,127] This causes secretion of adrenocorticotropic hormone (ACTH) from the anterior pituitary gland into the circulation followed by the release of glucocorticoids, such as cortisol, from the adrenal cortex.[125,127]

One potential neurobehavioral effect of stress is a decrease in executive control.[129] Executive control includes the cognitive processes used to control behavior, such as self-control and conscious decisions to stop or reduce intake of food.[129] Stress may reduce executive control through two mechanisms.[129] Activation of the sympathetic nervous system following a stressful event causes release of norepinephrine from a wide brain network of synapses and activation of the prefrontal dopamine system resulting in release of dopamine.[129,130] High levels of norepinephrine and dopamine in the prefrontal cortex (PFC), such as the dorsolateral PFC, is thought to impair executive control.[129,130] However, the mechanism is unclear. In addition, high levels of glucocorticoids that occur with HPA axis activation can cause glucocorticoids to bind to glucocorticoid receptors in the PFC.[129,131] The glucocorticoid receptors then function as transcriptional regulators, altering the expression of an estimated 70-100 genes in some areas

of the brain.[131] Though the effects are not currently clear and more research is needed, it has been hypothesized that this transcriptional regulation alters activity in the PFC, possibly impairing executive control.[129] Researchers suggest that our amount of executive control is limited.[132] Therefore, under stressful conditions, individuals may find it harder to control their eating behaviors, possibly resulting in overconsumption.

In addition to stress's effects on behavior through executive control, stress can make people seek out behaviors that may reduce the effects of stress. One action of glucocorticoids released with HPA axis activation, is to increase the salience, or importance and prominence, of pleasurable and compulsive behaviors, such as the intake of palatable foods.[125,133] Unfortunately, this means appetite is stimulated with effects on both amount and types of foods eaten.[125,127] In this way, cortisol is involved in regulating food choices and intake.[114] Evidence of this is found in research; those with the greatest release of cortisol with a stressful task have been found to eat more snack foods.[134] Consumption of highly palatable foods has the ability to attenuate the stress response through a reduction in activity in the HPA axis but at the high cost of caloric excess.[119,125]

Furthermore, eating involves both dopamine and opioid systems, which are involved in brain reward systems; dopamine motivates eating and opioids mediate hedonic aspects of eating.[121] Dopamine also has a role in sensitivity to stress and depression.[121] Palatable foods can activate regions of the brain involved in these reward systems, such as the striatum, insula, and thalamus, and produce behavioral reinforcement.[119,125] These foods also activate areas associated with pleasure, such as the orbitofrontal cortex and ventral pallidum, and can cause the release of opioids and endocannabinoids.[118] Under stressful conditions, individuals with obesity have been found to have increased activation in these areas in response to favorite food cues.[135] In this way, hyper-palatable foods can act as "comfort foods" and act as self-medication to reduce distress.[119]

In addition to changing energy intake, stress may also be involved in greater fat deposition and an unhealthy, centralized fat deposition pattern. Wardle et al. conducted a meta-analysis of 14 studies and found that stress was associated with higher adiposity, although the effects of stress were small.[120] In other research, high stress was positively correlated with abdominal fat.[136] One possible mechanism for this is that cortisol activates lipoprotein lipase, which makes triglycerides available, under proper circumstances, for incorporation into adipocytes.[137] The effect of this is promotion of lipid storage. The glucocorticoid receptor is present in a higher density in the intraabdominal adipose depot, resulting in more accumulation of fat centrally.[137] Furthermore, increased glucocorticoid concentrations may be associated with insulin and leptin resistance; increased stress and cortisol can impair sensitization of satiety signals and lead to weight gain, further insulin resistance, and greater risk of type 2 diabetes.[125,137]

Treatment of Obesity in the Context of Food Insecurity

There are many reasons why treatment of obesity in the context of food insecurity may be particularly difficult. It may be harder to treat low-income groups because this population may have a lack of transportation to treatment centers, lower literacy rates, language barriers, less available time, childcare necessities, and fewer resources available.[25] Because of barriers to health care, those with food insecurity may not receive as much preventative care to halt weight gain before it becomes obesity. In one study, adults with low incomes were less likely to have a regular doctor and less likely to have contacted a doctor in the previous 12 months compared to those with higher incomes.[138] Furthermore, behavioral interventions may not be used as often as they could for this population due to lack of referrals from health care providers, lack of availability of programs, patient inconveniences (the time and transportation

involved in receiving care), embarrassment of the patient, and financial costs.[22] Participant motivation has also been found to be an issue with some individuals of lower socioeconomic status.[25] Once considered obese and participating in weight loss treatment, those with food insecurity may have difficulty reaching weight loss goals. In our previous research, we found that those with food insecurity were less likely to reach 5% and 10% weight loss success than those with food security.[139] Furthermore, other investigators have found that those with severe obesity in the two most disadvantaged quintiles were 40% less likely to receive bariatric surgery than those in the two least disadvantaged quintiles.[140]

One large factor affecting access to health care is health insurance coverage. Differences in insurance coverage between populations are hard to report as plans vary widely and change frequently. However, it has been found that those with no insurance or public insurance other than Medicare were more likely to report food insecurity.[63,141] Those without health insurance may pay more for health care compared to those who are insured.[141] This can be an especially difficult situation for those with low incomes as it may force individuals to decide between paying for medical bills and medications or buying food.[141]

For those with public insurance other than Medicare, many are enrolled in Medicaid, which is federal insurance for those with low incomes. Those enrolled in Medicaid have a high prevalence of obesity compared to other forms of insurance.[142] This could be due to confounding variables but the types of services that are covered or not covered by Medicaid may be a contributor or may not help to ameliorate obesity in this population. This relationship can be difficult to understand because the services covered by Medicaid vary from state to state and year to year.[142] Nevertheless, as of 2010, all state Medicaid programs covered at least one type of obesity treatment.[142] However, there were major coverage gaps found, which could affect food-insecure individuals; 20 states explicitly did not cover nutrition counseling and only ten states covered

drug therapy.[142] As the newer weight loss medications are expensively priced and unavailable in generic forms, these are likely unavailable to the food-insecure population if they do not have insurance coverage. Bariatric surgery was most likely to be covered, as 45 states covered it.[142] However, this would not be offered unless individuals had more severe obesity, leaving many, with less severe forms of obesity, without insurance coverage for their obesity treatment.

With all the different factors involved in the food insecurity and obesity relationship, especially the role stress and perceived scarcity can have on intake, simple interventions are likely to be ineffective. It is possible that some interventions, such as restrictive dieting, could even be harmful.[81] Even though it may seem counterproductive, it might be necessary to improve an individual's food security, through increased food availability, to improve the quality of their energy intake, eating behavior, and health.[81] This population does not need less food to treat obesity, but rather better access to healthy food.[81] Interventions that help empower individuals to gain control of their food supply, such as gardening, financial planning, or meal planning may accomplish this.

An integrative review of weight loss interventions in low-income women with obesity found a number of factors that were included in successful interventions, including a group structure, peer educators, practical nutrition advice, and increased physical activity.[143] A group structure helped participants feel accepted and supported.[143] Peer interventions involved the training of a developed weight loss curriculum to lay community members.[143] Peer educators shared the culture, language, and social challenges of participants which led to a greater feeling of trust among participants.[143,144] In addition, these interventions were cheaper because they did not require as much time from medical professionals and there was greater program sustainability, as community members could continue the program without outside support.[143,145] Furthermore, practical nutrition advice, that was culturally and economically appropriate, was

important to successful interventions. Advice such as recipe sharing, portion control, healthy foods on the go, planning healthy meals, low-cost substitutions, and consuming calorie-free beverages have been used.[143] Finally, it was found that those who exercised during the interventions lost more weight than those that did not.[143] Most of these interventions used an increase in walking for physical activity.[143] There were the most barriers to this part of the intervention, as many participants were worried about their safety.[143] This included worries that no one would help if they fell, high crime, and busy traffic.[143]

Use of technology in weight loss interventions is also promising. There are web-based interventions that use websites to provide self-guided interventions to educate and create positive behavior changes.[22] These types of programs may involve goal-setting tools, alarms or reminders, BMI calculators, tracking of food or exercise, and social networking.[22] These materials can be customized to different languages, literacy levels, and schedules.[25] In a review of multiple studies, these programs have been found to result in more weight loss compared to controls but less than that lost with in-person interventions.[22] When combined with in-person interventions, subjects lost more weight compared to those with only in-person interactions.[22] These programs are lower cost, more adaptable, anonymous, and able to reach many patients.[22] Problems with these types of interventions include that they have not been tested on individuals of low socioeconomic status, there may be limited access for some populations that may need it the most (those with limited access to technology), possible communication problems between the intervention and participants, breaches in confidentiality, and difficulties with provider reimbursement.[22] The use of technology in nutrition interventions is an important area for future research.

Summary and Conclusion

Obesity is a complex issue that has increased dramatically over recent decades. This is a problem as obesity may increase the risk for various health conditions. Food insecurity, which occurs in about 12.7% of US households, has been found to increase the risk of obesity.[37] This could be because those with food insecurity consume fewer meals and more snacks and may have higher rates of disordered eating behaviors. In addition, this population has been found to consume poorer diets, higher in total and saturated fat, high-fat dairy, processed meats, and SSB, and lower in fruits and vegetables. Those with food insecurity also may have limited access to healthy foods or limited funds to purchase more expensive, healthy foods, which could increase the risk of obesity. In addition, the psychology involved in alternating periods of abundance and scarcity caused by food and nutrition assistance programs can increase energy intake over what is needed. Lastly, those with food insecurity may have higher levels of stress, which may change food preferences, food salience and the amount of food that individuals consume. Stress may also play a role in the deposition of fat, especially in the abdominal area.

Successful weight loss interventions have occurred with food-insecure populations. Some of these interventions have included group structures, peer educators, practical nutrition advice, increased physical activity, and the use of technology. However, obesity still may be harder to treat in this population due to the additional barriers to care that they may face, such as lack of transportation, resources, and time. The health insurance that individuals have may also affect treatment. Many individuals with food insecurity have Medicaid, which may not have coverage for services that they need. Possibly because of these barriers, we previously found that those with obesity and food insecurity were less likely to reach weight loss goals. Therefore, with this project, we aimed to determine underlying factors correlated with food insecurity in our population with obesity.

Chapter 2: Obesity and Food Insecurity in an Academic Weight Management Clinic

Introduction

Our group has been evaluating medical records and intake assessments in our patient population with obesity at the University of Minnesota Adult Medical Weight Management Clinic to better understand this population and improve treatment outcomes. In our earlier work (manuscript in preparation), a number of factors were examined in relation to subsequent weight loss success, including demographic factors, self-reported eating patterns and behaviors, and self-reported food insecurity. We found that food insecurity was the single factor most correlated with the amount of weight lost. Those who reported food insecurity lost an average of 1.2 pounds per 30 days compared to 3.5 pounds per 30 days for those who did not report food insecurity. Those with food insecurity were also less likely to reach 5% and 10% weight loss success. In addition, those with food insecurity were less likely to return for a follow-up appointment at 6 months ± 20% (145 to 215 days), suggesting possible barriers to receiving care. Therefore, we set out to follow-up on our group's earlier findings to determine factors correlated with food insecurity in this population, which might further explain the prior results.

Objective and Hypotheses

Building upon our earlier findings of the correlation of food insecurity with lack of weight loss success, we aimed to determine underlying factors correlated with food insecurity within a population with obesity at an academic weight management clinic to identify factors which are not currently being addressed in this population. We hypothesized that food insecurity would be positively correlated with being non-white, being unemployed or on disability, and having mental health conditions, specifically depression and anxiety, which could impact the ability to adhere to a weight loss regimen.

Methods

Data for this project came from two main sources: data extraction from electronic medical records (EMRs) and intake assessments. Food security was assessed by questions on the intake assessment while other variables came from the EMR, the intake assessment, or some combination. Trend tests, chi-square tests, and logistic regression were completed to analyze the data. This section will cover an in-depth description of the procedure used.

Data Extraction

Patient encounter data from the University of Minnesota Adult Medical Weight Management Clinic were extracted from two separate EMR systems, Allscripts and EpicCare, as a part of a project to analyze treatment outcomes at the Adult Medical Weight Management Clinic. Clinic visit data were extracted from March 1, 2010, to September 10, 2012. During this time, the clinic was undergoing a transition from Allscripts to EpicCare EMR, and patient records were stored in either Allscripts, EpicCare, or both. UMP IT data analysts extracted data regarding patient records associated with the adult weight management clinic physicians, dietitians, and lead nurse. Allscripts and EpicCare data from individuals who had agreed to have their data used for analysis were then combined into one database for analysis. The total population of extracted data included clinic encounter records for 1,174 unique patients. In the current analysis, data from those patients who had their first visit during the specified period and had completed an intake assessment, which totaled 360 consecutive patients, were utilized.

Intake Assessments

Intake assessments were also used for this project. These assessments were completed by patients who were new to our clinic and were used to develop

individualized treatment plans. These questionnaires contain questions regarding demographic information, medical history, weight history, previous weight loss attempts, eating habits, physical activity, and behavior and attitude toward change. Intake assessments from March 1, 2010, to September 10, 2012, were matched to patients from the data extraction based on first and last name and date of birth. This process resulted in a study population of 360 patients.

Food Security Assessment

Food security was evaluated by responses to three binary (yes/no) questions on the intake assessment: “Worry about not having enough food to eat,” “Have been to the food shelf at least a few times this year,” and “Lack of money keeps me from eating a healthy diet.” These questions were to be checked by the patient if they were true. Lack of positive response was considered a negative response. The number of questions marked positive was totaled for a score between 0 and 3. A score of 0 was considered food secure, while a score of 1 was considered marginally food secure. Food security levels of 2 and 3 were combined due to a lower number of patients in those categories. These patients were considered food insecure.

Variable Coding

Data for additional variables of interest came from either medical records or intake assessments. Data for age, weight, BMI, SBP, DBP, and insurance were extracted from the medical record for the patient’s first visit. Sex, race, and history of bariatric surgery were also extracted from the medical record. Data points that were not recorded in the medical record were marked as missing. For marital status, employment, and tobacco use, data from the intake assessment and chart reviews were combined. When the data point was missing from either the medical records or intake assessment, the data from the other source was

used. Any data points that were missing from both the intake assessment and the medical record and data points that disagreed between the two data sets were marked as missing and excluded from analysis. Data for all other variables were obtained from the intake assessments. Questions that were not answered by the subject were marked as missing.

Two questions from the Patient Health Questionnaire (PHQ) were present on the intake assessments. On the PHQ, participants self-report frequency of signs of depression from the Diagnostic and Statistical Manual of Mental Disorders IV (DSM-IV) over the previous two weeks. The PHQ has been validated for use diagnosing depressive disorders along with assessing depression severity.[146] The intake assessment asks, “Over the past two weeks, how often have you been bothered by any of the following problems?” This question is followed by “Having little interest or pleasure in doing things?” and “Feeling down, depressed, or hopeless?” Patients were to check a response reporting the frequency.

Eating patterns and behaviors were evaluated utilizing the intake assessment. Responses were categorized into six categories of eating patterns and behavior, including preventative medical eating, disordered eating patterns, hunger perception, emotional eating, craving, and binging (Table 2). Answers to these questions were coded as 1 for a positive response (yes/often) and 0 for a negative response (no/never). However, the question, “I eat at regular times in the day” was coded as 0 for a positive response and 1 for a negative response. The score in each category was then totaled and divided by the number of questions in that category for a score on a scale of 0 to 1.

Table 2. Eating Pattern and Behavior Assessment

Eating Patterns and Behaviors	Intake Assessment Questions
Preventative Medical Eating	• I have stomach acid or pain and eating makes it feel better • I eat extra snacks to prevent or correct low blood sugars
Disordered Eating Patterns	• I wake up at night to eat • I eat at regular times in the day, that is breakfast, lunch, dinner • I eat most of my food at the end of the day • Most of the food I eat requires very little cooking or preparation • I eat most of my meals in front of the TV or computer
Hunger Perception	• I feel hungry all the time, even if I have just eaten • Feeling full after a meal is important to me • I try not to let myself ever get hungry
Emotional Eating	• I eat when I'm depressed, stressed, bored, or to reward myself
Craving	• I feel like I am always thinking about food • When I have a craving, I try not to give in but usually end up giving in
Binging	• I find myself hiding food or food wrappers • Once I start eating I have a hard time stopping • I tend to over eat. For example, I can eat almost a whole box of cereal, a large bag of chips, or a loaf of bread in one sitting • I feel out of control when I eat • I eat until I am uncomfortably full • I feel bad about myself or guilty after I overeat

Statistical Analyses

Statistical analyses were done using SAS Version 9.4 (SAS Institute, Cary, NC) to determine whether there was a significant relationship between food security status and other variables in our population. Data were summarized by food security status as frequency and percentage for categorical data and mean and standard deviation for continuous variables. Jonckheere's trend test (continuous and ordinal categorical covariates) and the Cochran-Armitage trend

test (binary covariate) were used to determine if there was a trend across increasing food insecurity groups. Trend tests were used to detect a significant increase or decrease in the mean of a continuous variable or percentage of a binary variable as one increases in food insecurity. These tests were two-sided. Pearson chi-square was used for the remaining variables. These variables were categorical with more than two categories and non-ordinal. Statistical significance was defined as $p < 0.05$.

In addition, multivariable logistic regression with food insecurity as the dependent variable (no food insecurity versus any level of food insecurity) was done to determine which factors had the largest impact on food security. Key demographic variables and mental health variables were used as these were of most interest. Age, BMI, marital status, employment status, tobacco use, depression, anxiety, and history of abuse were put into the model originally. The variable with the highest p-value was removed, and the test was rerun. This procedure was done until no p-value was greater than 0.2.

Results

Descriptive Statistics

With a total sample size of 360 individuals, 66% were food secure, 22% were marginally food secure, and 12% were food insecure. “Lack of money keeps me from eating a healthy diet” was reported by 93% of those with food insecurity and 64% of those with marginal food security. “Have been to the food shelf a least a few times this year” was reported by 88% of those with food insecurity and 18% of those with marginal food security. Finally, “worry about not having enough food to eat” was reported by 35% of those with food insecurity and 19% of those with marginal food security.

Our population was 74% female with no difference in gender between food security groups (p-trend = 0.35; Table 3). Our population had an average

age of 45 years (SD = 12.9 years), ranging from 18 to 78 years old. As the level of food insecurity increased, average age decreased from 46.5 years (SD = 13.4 years) for individuals with food security to 42.3 years (SD = 11.3 years) for individuals with food insecurity (p-trend = 0.02). There was no significant difference in race (p-trend = 0.17); however, data were only available for 51% of our population. The population with food insecurity was more likely to be single (76.2% vs. 48.7%; p-trend < 0.001) as well.

Table 3. Study Population Demographics

	Food Secure	**Marginal Food Security**	**Food Insecure**	**p-trend**
	Mean (SD) or N (%)	Mean (SD) or N (%)	Mean (SD) or N (%)	
Total N = 360	N = 237	N = 80	N = 43	
Female	174 (73.4%)	59 (73.8%)	35 (81.4%)	0.35
Age (years)	46.5 (13.4)	43.3 (11.8)	42.3 (11.3)	0.02
Race (N = 185)				
White/Caucasian	104 (84.6%)	38 (86.4%)	12 (66.7%)	0.17
Non-white	19 (15.5%)	6 (13.6%)	6 (33.3%)	
Marital Status (N = 352)				
Single	112 (48.7%)	49 (61.3%)	32 (76.2%)	<0.001
Partnered	118 (51.3%)	31 (38.8%)	10 (23.8%)	

Those with food insecurity were more likely to be either on disability (54.8% vs. 12.9%) or unemployed (23.8% vs. 9%; p < 0.001; Table 4). Among those that were employed (21.4% of those with food insecurity vs. 71.1% of those with food security), those who were food insecure were less likely to be employed full-time (75% vs. 86.2%; p-trend = 0.01). There was no difference in the percentage of an individual's job spent on the phone or computer between groups (p = 0.18).

Table 4. Employment Status

	Food Secure	Marginal Food Security	Food Insecure	p-value
Employment Status (N = 354)				
Employed	165 (71.1%)	41 (51.3%)	9 (21.4%)	
Disability	30 (12.9%)	29 (36.3%)	23 (54.8%)	<0.001
Unemployed	21 (9%)	10 (12.6%)	10 (23.8%)	
Retired	16 (6.9%)	0 (0%)	0 (0%)	
Employment Status if Employed (N = 206)				**p-trend**
Full Time	137 (86.2%)	26 (66.7%)	6 (75%)	0.01
Part Time	22 (13.8%)	13 (33.3%)	2 (25%)	
Percentage of Job Spent on the Phone or Computer (N = 209)				**p-trend**
Less than 50%	52 (32.1%)	18 (46.2%)	3 (37.5%)	
50%	20 (12.4%)	5 (12.8%)	2 (25%)	0.18
75%	51 (31.5%)	7 (18%)	1 (12.5%)	
100%	39 (24.1%)	9 (23.1%)	2 (25%)	

Health Care Access. Individuals with food insecurity were much more likely to have Medicaid insurance compared to individuals with food security (37.8% vs. 7.2%; p-trend < 0.001; Table 5). Individuals with food insecurity were also more likely to have insurance through a health maintenance organization (HMO) (46% vs. 29.8%; p-trend = 0.005) and less likely to have indemnity insurance (8.1% vs. 44.2%; p-trend < 0.001). There were no differences in rates of preferred provider organization (PPO) and Medicare insurance between groups (p-trend = 0.09 and 0.11, respectively).

Furthermore, there were no differences in the average number of visits to the weight management clinic (p-trend = 0.34), length of follow-up (p-trend = 0.99), and visits per 30 days (p-trend = 0.81) between levels of food security.

Table 5. Health Care Access

	Food Secure Mean (SD) or N (%)	Marginal Food Security Mean (SD) or N (%)	Food Insecure Mean (SD) or N (%)	p-trend
Insurance Coverage (N = 318)				
HMO	62 (29.8%)	36 (49.3%)	17 (46%)	0.005
Indemnity	92 (44.2%)	20 (27.4%)	3 (8.1%)	<0.001
PPO	45 (21.6%)	9 (12.3%)	5 (13.5%)	0.09
Medicaid	15 (7.2%)	13 (17.8%)	14 (37.8%)	<0.001
Medicare	43 (20.7%)	24 (32.9%)	10 (27%)	0.11
Summary of Follow-Up (N = 360)				
Number of visits	2.1 (1.5)	2.3 (1.7)	1.7 (1.5)	0.34
Length of follow-up (days)	156.6 (130.9)	184.6 (197.9)	150.6 (152.8)	0.99
Visits per 30 days	0.9 (0.6)	0.8 (0.4)	0.9 (0.5)	0.81

Physical Comorbidities. There were some differences in health status between food security groups. In our patient population, those reporting food insecurity had higher baseline BMIs compared to individuals with food security (46.5 vs. 40.9 kg/m^2; p-trend = 0.005; Table 6). Those with food insecurity were more likely to report having diabetes (34.9% vs. 19.8%; p-trend = 0.02), lymphedema (39.5% vs. 20.3%; p-trend = 0.001), and pain (86.1% vs. 68.4%; p-trend = 0.01), specifically back pain (62.8% vs. 46.4%; p-trend = 0.01). There was no difference in BMI between those with diabetes and those without it (p = 0.25, data not shown). However, BMI was statistically different between those with lymphedema (p < 0.001), pain (p < 0.001), and back pain (p = 0.008) and those without these conditions. There were no differences in other medical comorbidities between food security groups. There also were no differences in SBP (p-trend = 0.49) or DBP (p-trend = 0.66) or history of bariatric surgery (p-trend = 0.39; data not shown).

Table 6. Physical Comorbidities

	Food Secure	Marginal Food Security	Food Insecure	p-trend
	Mean (SD) or N (%)	Mean (SD) or N (%)	Mean (SD) or N (%)	
Physical Comorbidities (N = 360)				
Diabetes	47 (19.8%)	22 (27.5%)	15 (34.9%)	0.02
Pre-diabetes	27 (11.4%)	7 (8.8%)	2 (4.7%)	0.16
Heart disease	19 (8%)	10 (12.5%)	6 (14%)	0.14
High cholesterol	90 (38%)	35 (43.8%)	19 (44.2%)	0.31
Pain	162 (68.4%)	60 (75%)	37 (86.1%)	0.01
Back pain	110 (46.4%)	48 (60%)	27 (62.8%)	0.01
Knee pain	116 (49%)	41 (51.3%)	28 (65.1%)	0.08
Feet pain	82 (34.6%)	30 (37.5%)	19 (44.2%)	0.23
Lymphedema	48 (20.3%)	28 (35%)	17 (39.5%)	0.001
Heartburn or acid reflux	82 (34.6%)	33 (41.3%)	13 (30.2%)	0.99
Liver problems	17 (7.2%)	6 (7.5%)	1 (2.3%)	0.35
Kidney disease	16 (6.8%)	4 (5%)	5 (11.6%)	0.46
Sleep apnea	75 (31.7%)	24 (30%)	15 (34.9%)	0.82
CPAP or BiPAP[a]	43 (72.9%)	16 (80%)	7 (63.6%)	0.79
High blood pressure[b]	81 (39.7%)	23 (34.3%)	17 (46%)	0.86
Low thyroid[b]	34 (16.7%)	9 (13.4%)	6 (16.2%)	0.69
Polycystic ovarian syndrome[c]	12 (6.9%)	2 (3.4%)	2 (5.7%)	0.55
Problem getting pregnant[c]	7 (4%)	3 (5.1%)	3 (8.6%)	0.28
Vital Signs				
Weight (lbs)[d]	258 (68)	260.9 (58.1)	277 (87.7)	0.13
BMI (kg/m^2)[e]	40.9 (8.9)	42.6 (7.8)	46.5 (12.8)	0.005
SBP (mmHg)[f]	130.2 (13.7)	129.6 (13.8)	127.9 (17.8)	0.49
DBP (mmHg)[f]	77.3 (11.2)	76.6 (10.8)	78 (13.2)	0.66

[a] N = 90, [b] N = 308, [c] N = 269, [d] N = 307, [e] N = 304, [f] N = 302

There were no statistically significant relationships between food security and family history of overweight and obesity (data not shown). This analysis included overweight and obesity among fathers (p-trend = 0.82), siblings (p-trend = 0.44), spouses (p-trend = 0.22), and children (p-trend = 0.81). However, having a mother with overweight or obesity (p-trend = 0.07) and reporting that many relatives are overweight or obese (p-trend = 0.08) were slightly more common

amongst those with food insecurity. Finally, there was no difference in those reporting that they were the only person in their family with overweight and obesity between food security groups (p-trend = 0.74).

Mental Health Comorbidities. Those with food insecurity were 37% more likely to report depression compared to individuals with food security (60.5% vs. 44.3%; p-trend = 0.007; Table 7). The link between depression and food insecurity was also seen in the responses to the PHQ questions. Those with food insecurity tended to report feeling little interest or pleasure in doing things or feeling down, depressed, or hopeless with greater frequency compared to individuals with food security (p-trend = 0.003 and < 0.001, respectively). Individuals with food insecurity were also 48% more likely to report anxiety (48.7% vs. 32.8%; p-trend = 0.004) and twice as likely to report a history of sexual or physical abuse (47.6% vs. 23.7%; p-trend < 0.001) compared to those with food security.

Table 7. Mental Health Comorbidities

	Food Secure	Marginal Food Security	Food Insecure	p-trend
Depression[a]	105 (44.3%)	49 (61.3%)	26 (60.5%)	0.007
Anxiety[b]	67 (32.8%)	38 (55.9%)	18 (48.7%)	0.004
Physical or Sexual Abuse (N = 346)				
History of abuse	54 (23.7%)	28 (36.8%)	20 (47.6%)	<0.001
PHQ2. Little Interest or Pleasure in Doing Things (N = 287)				
Not at all	82 (43.4%)	23 (37.1%)	6 (16.7%)	0.003
For several days	53 (28%)	12 (19.4%)	15 (41.7%)	
More than half the days	34 (18%)	10 (16.1%)	9 (25%)	
Nearly every day	20 (10.6%)	17 (27.4%)	6 (16.7%)	
PHQ2. Feeling Down, Depressed, or Hopeless (N = 290)				
Not at all	101 (52.9%)	24 (38.1%)	10 (27.8%)	<0.001
For several days	50 (26.2%)	18 (28.6%)	11 (30.6%)	
More than half the days	32 (16.8%)	9 (14.3%)	10 (27.8%)	
Nearly every day	8 (4.2%)	12 (19.1%)	5 (13.9%)	

[a] N = 360, [b] N = 308

Life Events Affecting Weight Gain. On the intake assessment, patients were asked whether they believed their weight gain was related to one of the following events: starting a medication, a health crisis, a personal crisis, quitting smoking, stopping an addictive drug or alcohol abuse, or something else (with space to explain). None of the conditions were statistically significant between groups (Table 8). However, weight gain due to a personal crisis approached significance (p-trend = 0.054), with individuals with food insecurity trending to be more likely to report a past personal crisis causing weight gain (39.5% vs. 26.2%). This question asked subjects to describe their personal crisis if they marked this question as true. The most common response, reported by 23 subjects, involved the death of family members or friends, including mothers, fathers, grandparents, and children. The end of a long-term relationship was another common response, listed by 20 subjects. Thirteen subjects listed their own divorce as a personal crisis that led to their weight gain, while 3 listed the divorce of their parents. Other responses included “husband ran off,” “recently separated,” and “broken engagement.” Mental illness and stress were reported by 20 subjects as personal crises. Depression was listed by 11 individuals, stress by 6, and anxiety by 4. Abuse was reported by 13 subjects, including sexual, physical, and emotional abuse to the subject or their children. Lastly, 13 subjects listed problems related to employment status as a personal crisis, including job loss or unemployment of 7 subjects and stress of work or a new job. Other responses to this question included marital or family problems, illness/injury of family members, taking care of children, moving, homelessness, and education.

Table 8. Life Events Affecting Weight Gain

	Food Secure	Marginal Food Security	Food Insecure	p-trend
Starting a medication	68 (28.7%)	23 (28.8%)	9 (20.9%)	0.39
A health crisis	48 (20.3%)	19 (23.8%)	12 (27.9%)	0.23
A personal crisis	62 (26.2%)	26 (32.5%)	17 (39.5%)	0.054
Quitting smoking	24 (10.1%)	11 (13.8%)	4 (9.3%)	0.8
Stopping an addictive drug or alcohol abuse	11 (4.6%)	8 (10%)	1 (2.3%)	0.8

Tobacco and Alcohol Use. Those reporting food insecurity were 205% more likely to be smokers (26.2% vs. 8.6%; p-trend = 0.001; Table 9). Those with food insecurity reported less alcohol use frequency compared to the population with food security (p-trend = 0.009). Of those with food insecurity, 86% reported drinking alcohol “never” or “monthly or less,” compared to 78% of those with marginal food security, and 64% of those with food security. There were no differences in the number of alcoholic drinks consumed when drinking (p-trend = 0.24).

Table 9. Tobacco and Alcohol Use

	Food Secure	Marginal Food Security	Food Insecure	p-trend
Tobacco Use (N = 353)				
Non-smoker	213 (91.4%)	67 (85.9%)	31 (73.8%)	0.001
Smoker	20 (8.6%)	11 (14.1%)	11 (26.2%)	
Alcohol Consumption Frequency (N = 294)				
Never	64 (33.7%)	31 (46.3%)	14 (37.8%)	
Monthly or less	58 (30.5%)	21 (31.3%)	18 (48.7%)	
2-4 times/month	41 (21.6%)	12 (17.9%)	3 (8.1%)	0.009
2-3 times/week	16 (8.4%)	2 (3%)	2 (5.4%)	
4 or more times/week	11 (5.8%)	1 (1.5%)	0 (0%)	
Alcohol Consumption Drinks Per Day (N = 167)				
1 or 2	93 (81.6%)	26 (81.3%)	14 (66.7%)	
3 to 4	16 (14%)	4 (12.5%)	5 (23.8%)	0.24
5 to 6	3 (2.6%)	2 (6.3%)	1 (4.8%)	
7 to 9	2 (1.7%)	0 (0%)	1 (4.8%)	

Non-alcoholic Beverage Consumption. There were many reported differences between levels of food security when it came to non-alcoholic beverage consumption (Table 10). Individuals with food insecurity reported drinking twice as much juice (0.8 vs. 0.4 glasses/day; p-trend = 0.03), 267% more drink mix (1.1 vs. 0.3 glasses/day; p-trend < 0.001), and 386% more sugar soda or sports type drink (17.5 vs. 3.6 oz/day; p-trend < 0.001) compared to individuals with food security. There was no trend in diet soda consumption between groups (p-trend = 0.46). There was also no difference in the amount of milk consumed between groups (p-trend = 0.65), but individuals with food insecurity reported drinking milk with a higher fat content (p < 0.001). Those with food security were most likely to report drinking skim milk, while 1% milk was the most popular for those with marginal food security, and 2% milk was the most popular for those reporting food insecurity.

Table 10. Non-alcoholic Beverage Consumption

	Food Secure Mean (SD) or N (%)	**Marginal Food Security** Mean (SD) or N (%)	**Food Insecure** Mean (SD) or N (%)	**p-trend**
Sugar soda/sports type drinks (oz/day)[a]	3.6 (10.1)	8.5 (20.6)	17.5 (24.9)	<0.001
Diet soda (oz/day)[b]	13 (19.5)	16.3 (25.2)	3.8 (9.2)	0.46
Juice (glasses/day)[c]	0.4 (0.8)	0.4 (0.8)	0.8 (1)	0.03
Drink mix (glasses/day)[d]	0.3 (0.8)	0.8 (1.5)	1.1 (1.8)	<0.001
Milk (glasses/day)[e]	0.9 (1)	1 (1.4)	0.9 (1.1)	0.65
Type of Milk (N = 241)				
Skim	85 (53.1%)	15 (30%)	8 (25.8%)	<0.001
1%	40 (25%)	20 (40%)	6 (19.3%)	
2%	29 (18.1%)	15 (30%)	12 (38.7%)	
Whole	6 (3.8%)	0 (0%)	5 (16.1%)	

[a] N = 300, [b] N = 293, [c] N = 329, [d] N = 285, [e] N = 324

There were no reported differences between food security groups in fast food consumption (p-trend = 0.27; data not shown). However, individuals with food security reported visiting sit-down restaurants 1.26 times per week compared to 0.49 times per week for individuals with food insecurity (p-trend < 0.001).

Eating Patterns and Behaviors. We defined preventative eating as eating to relieve stomach acid or pain or eating to prevent or correct blood sugar. Individuals with food insecurity were 73% more likely to report preventative eating compared to individuals with food security (0.19 vs. 0.11 on a scale from 0 to 1; p-trend = 0.03; Table 11). However, when this category was broken down by question, neither question was significantly different between groups. However, the preventative eating relationship was likely driven by the question “I have stomach acid or pain, and eating makes it feel better,” which, at a trend level, was slightly more frequent among individuals with food insecurity (0.25 vs. 0.1; p-trend = 0.08). Hunger perception was significantly different between groups (p-trend = 0.003), with individuals with food insecurity reporting 81% more positive responses within this category (0.49 vs. 0.27). Broken down by question, only “feeling full after a meal is important to me” was significantly greater in the population with food insecurity (0.83 vs. 0.36; p-trend = 0.009). “I try not to let myself get hungry” was marginally significant (0.46 vs. 0.37; p-trend = 0.053) but there was no difference in “I feel hungry all the time, even if I have just eaten” (p-trend = 0.2). There were no differences in disordered eating patterns (p = 0.07), emotional eating (p = 0.79), craving (p = 0.48), and binging (p = 0.07) between groups.

Table 11. Eating Patterns and Behaviors

	Food Secure Mean (SD)	Marginal Food Security Mean (SD)	Food Insecure Mean (SD)	p-trend
Eating Patterns and Behaviors (N = 217)				
Preventive eating	0.11 (0.22)	0.18 (0.27)	0.19 (0.29)	0.03
Disordered eating patterns	0.39 (0.25)	0.43 (0.27)	0.48 (0.2)	0.07
Hunger perception	0.27 (0.27)	0.32 (0.31)	0.49 (0.22)	0.003
Emotional eating	0.66 (0.46)	0.67 (0.46)	0.67 (0.48)	0.79
Craving and binging	0.32 (0.24)	0.38 (0.26)	0.37 (0.25)	0.16
Binging	0.27 (0.24)	0.33 (0.26)	0.33 (0.25)	0.07
Craving	0.45 (0.38)	0.5 (0.37)	0.48 (0.35)	0.48
Preventive Eating				
I have stomach acid or pain and eating makes it feel better	0.1 (0.31)	0.14 (0.35)	0.25 (0.44)	0.08
I eat extra snacks to prevent or correct low blood sugars	0.13 (0.34)	0.27 (0.45)	0.13 (0.34)	0.18
Hunger Perception				
I feel hungry all the time, even if I have just eaten	0.28 (0.44)	0.39 (0.47)	0.31 (0.44)	0.2
Feeling full after a meal is important to me	0.36 (0.48)	0.33 (0.47)	0.83 (0.38)	0.009
I try not to let myself get hungry	0.16 (0.37)	0.23 (0.42)	0.31 (0.46)	0.053

Barriers to Physical Activity. Individuals with food insecurity were more likely to report pain (74.4% vs. 53.2%; p-trend = 0.004), shortness of breath (44.2% vs. 27.4%; p-trend = 0.004), and being unsure what to do (30.2% vs. 12.7%; p-trend = 0.005) as barriers to being more active (Table 12). Both pain and shortness of breath were correlated with BMI (p = 0.01 and < 0.001, respectively, data not shown). However, being unsure what to do (p = 0.2) was not. Those with food insecurity were less likely to report lack of time as a barrier to physical activity than those with food security (14% vs. 28.9%; p-trend =

0.045). There was no difference in being worried people would look at them (p-trend = 0.14) or being too tired (p-trend = 0.62) between groups.

Table 12. Barriers to Physical Activity

	Food Secure	Marginal Food Security	Food Insecure	p-trend
Pain	126 (53.2%)	51 (63.8%)	32 (74.4%)	0.004
Short of breath	65 (27.4%)	35 (43.8%)	19 (44.2%)	0.004
Lack of time	66 (28.9%)	18 (22.5%)	6 (14%)	0.045
Worried people will look at me	33 (13.9%)	16 (20%)	9 (20.9%)	0.14
Unsure what to do	30 (12.7%)	14 (17.5%)	13 (30.2%)	0.005
Too tired	111 (46.8%)	44 (55%)	20 (46.6%)	0.62

Readiness and Confidence in Change. Despite all other reported differences between food security groups, there was no difference in readiness to make changes (average of all groups = 8.6; p-trend = 0.98) and confidence in change (average 7.4; p-trend = 0.47) when reported on a scale from 0 to 10 between food security groups (Table 13).

Table 13. Readiness and Confidence in Change

	Food Secure	Marginal Food Security	Food Insecure	p-trend
	Mean (SD)	Mean (SD)	Mean (SD)	
Ready to change[a]	8.7 (1.6)	8.4 (1.8)	8.7 (1.9)	0.98
Confidence in change[b]	7.5 (2.1)	7.1 (2.3)	7.3 (2.4)	0.47

[a] N = 349, [b] N = 346

Logistic Regression

A multivariable logistic model using factors with the strongest univariate correlations was analyzed to predict food security status (Table 14). Marital status, tobacco use, and depression were removed from the model, in that order, due to having the highest p-values. In the final model, BMI (p = 0.11) and anxiety

(p = 0.06) were the least statistically significant with age (p = 0.03), disability (p < 0.001), unemployment (p = 0.02), and abuse history (p = 0.04) remaining the most related to food insecurity.

Table 14. Logistic Regression

	Odds Ratio	p > |z|	95% Confidence Interval	
Age	0.86	0.03	0.75	0.99
BMI	1.15	0.11	0.97	1.36
Disability	7.86	<0.001	3.63	17
Unemployment	2.93	0.02	1.17	7.34
Anxiety	1.86	0.06	0.98	3.53
History of abuse	2.08	0.04	1.05	4.12

Discussion

We set out to determine underlying factors correlated with food insecurity in a population with obesity at an academic weight management clinic because we previously found that those with food insecurity were less likely to reach weight loss goals. In our follow-up analysis, we found that those with food insecurity were much more likely to consume sugar sodas, sports drinks, juice, and drink mixes, potentially high in empty calories, compared to those with food security. We also found that depression, anxiety, and history of physical or sexual abuse were higher among those with food insecurity compared to those with food security. Furthermore, in our population of weight management clinic patients, BMI increased as the reported number of food security-related issues increased. In addition, despite having higher BMIs compared to food-secure individuals, those with food insecurity placed more importance and value on “feeling full” after a meal compared to those with marginal food security or food security. This finding raises the possibility that having food insecurity could effect changes in food salience, including changes to food choices and portions when food is available, in susceptible individuals.

Within our population of individuals with obesity seeking weight loss, we found that those with food insecurity were more likely to be younger, similar to what has been seen in previous research with NHANES data.[42] We also found that those with food insecurity were more likely to report being single. This relationship is similar to previous research on the general population, in which investigators have found that individuals that are separated, divorced, or living alone have higher rates of food insecurity.[37,41] Our results add to previous data by showing that these trends are also present in individuals with obesity. Younger and single individuals are potentially less established in their lives and careers and may be working jobs that pay less. In addition, those living with others may have more than one individual with a job within the household, increasing income for the group, and thus reducing the risk of food insecurity.

We did not find a relationship between food insecurity and gender, contrary to some previous research in this area.[43] This could be because we were specifically looking at a population with obesity, most of whom were women; women who have obesity may be more likely to seek weight loss treatment than men with obesity.[2] We also found no difference in race between food security groups. This is different from what has been found by other researchers, who found that African American and Hispanic individuals may be more likely to be food insecure.[42] The difference between our results and others' could be because data regarding race were only available for just over half of our population and those of certain races may have been more or less likely to report their race. In addition, our population is from a single, university-based clinic, which could have influenced our results. Another demographic difference we found was that those with food insecurity were more likely to be on disability or unemployed. In addition, if individuals with food insecurity were employed, they were more likely to be employed part-time. This finding has been seen

previously; those with incomes near or below the federal poverty line have higher rates of food insecurity as, of course, would be expected.[37]

As health insurance is typically tied to employment, the significant differences we found in health insurance were not surprising. We found that those with food insecurity were more likely to have federal insurance through Medicaid compared to food-secure individuals. Similar results have been seen in previous studies, but not within a population with obesity.[22] This could be a problem as individuals with Medicaid may have a harder time accessing care. It has been found multiple times that when calling to schedule an appointment, researchers claiming to have private insurance were more likely to receive appointments than those who claimed to have Medicaid insurance.[147–149] The most common reason for denying an appointment in one study was that the practice was not accepting Medicaid insurance.[147] Furthermore, it has been found that fewer preventative services were ordered for women with Medicaid, including clinical breast exams and Pap tests.[150] It is possible that obesity-related care, including dietitian and mental health provider benefits, may not be covered as well by Medicaid as by private insurance. Even if there is not a difference in private vs. Medicaid reimbursement rates, those with private insurance would still likely be better able to afford any additional costs, such as co-pays.

In addition to being more likely to be coved by Medicaid, individuals with food insecurity were more likely to have insurance through an HMO compared to food-secure individuals. HMOs are health insurance plans that usually limit coverage to care from doctors who work for or contract with the HMO. HMOs, along with PPOs, are the most common types of health care plans offered by employers. These plans vary widely based on the insurance company and individual plan, making this result difficult to interpret. We also found that those with food insecurity were less likely to have indemnity insurance compared to food-secure individuals. This type of plan allows individuals to visit almost any

doctor or hospital they like; the insurance company then pays a set portion of the total charges. Many indemnity plans require people to pay up front and then submit a claim for reimbursement. Many also likely have an annual deductible. These requirements may make this type of plan harder for those with low incomes and food insecurity to manage.

In the current analysis, we found that there was no difference in the number of visits to the weight management clinic or length of follow-up time between food security groups. In our earlier analysis, in which we examined weight loss over a 6-month period, those with food insecurity were less likely to have a follow-up visit at the 6-month time point. We considered the possibility that those with food insecurity were less likely to return, but our current analysis counted all visits between March 1, 2010, and September 10, 2012, and we saw no differences between food security groups with regards to these measures of clinic follow-up. However, more research on access to care and insurance coverage adequacy for individuals with obesity and food insecurity is needed.

Differences in health care may be responsible for some of the differences we found in medical history between food security groups. In our population, BMI increased as the reported number of food security-related issues increased, although BMI averages for all food security groups would be classified as class III obesity, the most severe form.[1] Our findings concur with a review by Laraia that found that those with food insecurity had higher rates of obesity and higher BMIs compared to food-secure individuals.[53] However, this is the first time BMI, as a continuous factor, has been shown to be positively correlated with reported level of food insecurity within a population with obesity; it shows that not only are those with food insecurity at a higher risk of obesity, obesity may be more severe in those who report more food insecurity-related issues.

In addition to higher BMIs, individuals with food insecurity reported higher rates of some different medical comorbidities. Individuals with food insecurity

were more likely to report a history of lymphedema and pain, specifically back pain. However, these differences are likely due to our population with food insecurity having higher BMIs as BMI was statistically different between those with these conditions and those without them. Rates of back pain are high among those with overweight and obesity, likely due to increased mechanical load on the spine, higher rates of accidental injuries, or chronic inflammation leading to pain.[151] We also found that those with food insecurity were more likely to report having diabetes. This result is not attributable to BMI as there was no difference in BMI between those with diabetes and those without it. Seligman et al. also found correlations with diabetes and food security status; they found that those with food insecurity had higher rates of diabetes and less glycemic control.[47] Higher rates of diabetes among those with food insecurity could be due to those with food insecurity having diets that are not conducive to diabetes management,[62] limited or unstable food availability that could make regulating blood sugar difficult, or more difficulty affording supplies needed to manage diabetes.[62] Finally, in our analysis, reported prevalence of heart disease, hypertension, and measured high blood pressure were not statistically significant between food insecurity groups. However, some other investigators have found higher rates of heart disease and hypertension in those with food insecurity.[47,53,54] It should be noted that only a small percentage of our population reported heart disease, and perhaps the relatively young age of our subjects, especially those with food insecurity, may account for our findings.

With regards to the relationship between mental health and food insecurity, we found that those with marginal food security and food insecurity were much more likely to report depression and anxiety, which has been found in a number of prior studies.[39,66,67] This finding was corroborated by the reported higher frequency of experiencing the depressive symptoms of feeling little interest or pleasure in doing things and feeling down, depressed, or hopeless

among participants in our study, also seen by Leung et al.[39] Those with food insecurity were also much more likely to report a history of abuse. Investigators have found that those with food insecurity may have a higher exposure to violence.[70] Exposure to violence or a history of abuse may lead to many effects on mental health, including the inability to maintain a job, get an education, or have healthy relationships, all potential contributors to food insecurity.[70] The link between food insecurity and mental health problems may help explain why this population has a higher risk of obesity. It is possible that psychological stress in this population could change food preferences toward more highly palatable, higher calorie foods, which may promote obesity. Furthermore, individuals may increase the amount of food that they consume when under stress, increasing the risk for obesity. Research on stress and its effects on the amount consumed and food preferences in those with food insecurity is an important area for future research.

From our logistic regression analysis, we found that BMI, depression, and anxiety were highly correlated with food insecurity, with employment status and history of abuse being the most significantly independently related in the model controlling for the other factors. The role employment plays in this relationship is clear. The role a history of abuse plays is very interesting. It stresses the importance of the environment in the development of food insecurity and the fact that many of these individuals may have significant mental health problems, which need to be addressed if we want to improve both their food security and treat obesity. Likely related to these regression findings, our subjects with food insecurity tended to report a higher frequency of a personal crisis causing weight gain. Many individuals listed depression, anxiety, stress, and abuse as personal crises in the free text portion of this questionnaire section. Other common responses included the death of family or friends, family or marital problems, divorce, and problems regarding employment.

In addition to the differences in medical and personal history, we also saw a large difference in tobacco consumption across food security levels. As food insecurity increased in our population, so did likelihood of being a smoker. This trend has also been seen in research by Gowda et al.,[42] although not within a population with obesity. The correlation between smoking and food insecurity could be because a portion of these individual's incomes is going towards tobacco rather than food, increasing the risk for food security. It could also be because of the addictive nature of tobacco and less access to smoking cessation programs.[42]

Contrary to reported tobacco use, individuals with food insecurity in our study reported consuming alcohol less frequently compared those with food security. There was no difference in the amount of alcohol consumed on days when individuals were drinking. However, our data may have been underreported on this section of the questionnaire. Alcohol consumption among those with food insecurity is a topic where very little research has been done, and more research is needed.

In contrast to reported alcoholic beverage consumption, those with food insecurity reported drinking much more juice compared to those with food security and marginal food security. In addition, consumption of drink mixes and sugar sodas increased as the level of food insecurity increased. These results are similar to other findings that those with food insecurity and those participating in SNAP were found to consume more SSB compared to those with food insecurity or not participating in SNAP.[88,152] These consumption patterns may make this population more prone to obesity, type 2 diabetes, and cardiovascular disease.[91]

The message to consume less SSB is pervasive in society today, though it is possible that this population is not receiving this message. One of the biggest sources of this message is the Dietary Guidelines for Americans (DGA), which

recommends reducing consumption of SSB and replacing them with water. Following this recommendation could reduce dietary costs and improve the diet, as consumption of water is associated with various health benefits, including greater chances of reaching weight loss goals and less weight gain over time.[152] Education through SNAP uses the DGA as their source of nutrition education; the finding that this population is not more likely to meet SSB recommendations suggests problems with this message.[152] This could be because individuals are not receiving this message or because they do not have the guidance and support that they need to make behavior changes. Furthermore, this population may just consume what is available to them. For those that use food pantries or do not have access to a grocery store, SSB may be the only option. Lastly, populations of low socioeconomic status may have concerns about the safety of their tap water, further limiting their beverage choices.[153] We raise the additional possibility that susceptible individuals with food insecurity may develop changes in food salience leading to even greater preference for highly palatable foods, such as SSB, compared to more food-secure individuals.

Various strategies have been considered in an attempt to decrease SSB consumption. One suggestion that has been made is soda taxes. The first penny per ounce SSB excise tax in the United States was implemented in Berkeley, California in March 2015.[154] This type of tax was expected to be more influential to consumers as it causes higher shelf prices rather than a tax added at the register.[155] One year after implementation of this tax in Berkeley, the price of SSB increased in all store types except independent corner stores and gas stations, where prices decreased by 0.45 ¢/oz.[154] This resulted in the sales of SSB declining in Berkeley stores by 9.6%, while sales rose by 6.9% in non-Berkeley stores.[154] In addition, sales of untaxed beverages, especially water, increased 3.5% in Berkeley stores.[154] Investigators also found that there was no change in total consumer spending or reduction in store revenue.[154] However,

self-reported SSB intake did not change significantly from baseline based on phone surveys of 24-hour beverage recalls.[154] On the other hand, beverage frequency questionnaires of individuals in low-income neighborhoods in Berkeley showed a 21% decrease in SSB consumption compared to a 4% increase in comparison cities.[155] Results of this tax on SSB consumption are not completely clear now, but they present a promising opportunity to reduce SSB consumption, especially for those in low-income neighborhoods.

Looking at other beverages, we found no difference in consumption of diet soda or milk between food security groups. However, those with food insecurity tended to choose milk with a higher fat content. Similar results have been seen in previous research.[156] One study by Jones found that consumers in low-income areas purchase three times as much whole milk compared to consumers in high-income areas.[157] This is likely not due to price as researchers have found that in most stores, 1% milk or non-fat milk may cost less.[96] This finding may be because low-income areas and areas of low socioeconomic status have been found to have less availability of low-fat milk.[156,158] The availability of low-fat milk in an area was directly correlated with consumption of low-fat milk by households.[156] Furthermore, low-income population may also have a lack of health information about milk consumption or may purchase whole fat milk due to having small children in the household.[93] Lastly, focus groups of older, low-income women found that many did not like the taste of non-fat and low-fat milk.[159] Again, we raise the possibility that food insecurity could effect changes in food preference. Whatever the underlying contributors to this pattern of beverage consumption found in our patients, SSB and higher fat milk could contribute to caloric excess, leading to the higher BMIs seen in those with food insecurity in our population.

In addition to reported difference in energy consumption patterns, those with food insecurity reported differences in barriers to energy expenditure.

Individuals with food insecurity were more likely to report pain, shortness of breath, and being unsure what to do as barriers to physical activity. Pain as a barrier to physical activity makes sense, as those with food insecurity were also more likely to report pain on the medical comorbidities section of the intake assessment. Limited knowledge about health has been discussed previously as a difficulty that those with food insecurity may face, but there is little data to back up this claim. Feelings regarding barriers to physical activity may be necessary to address when working with individuals with food insecurity.

Despite all the differences between food security groups and the additional barriers that those with food insecurity may face, those with food insecurity did not report lower levels of readiness to change or lower levels of confidence in their ability to change. Much emphasis has been placed on motivating patients for successful behavior change. While it is important to motivate individuals effectively to help ensure successful behavioral changes to promote weight loss, a difference in reported baseline weight loss motivation related to food security status was not identified as a significant factor in our population. However, it is possible that subjects were providing answers they thought providers wanted to hear.

Finally, on the intake assessment, we also asked several questions related to hunger. As noted earlier, the importance of feeling full after a meal was much more common among those with food insecurity, despite having higher BMIs. This finding suggests the possibility that having food insecurity, especially in susceptible individuals, such as those in our clinic who are predisposed to having obesity, could potentially enhance food salience and alter appetite regulation. Altered appetite perception may push some with food insecurity to consume more per meal and increase their energy intake over what they might have consumed if not living under food-insecure conditions. This is an interesting area where more research is needed.

These results provide insights into differences between individuals with obesity seeking weight loss, in relation to food security status. However, there are some limitations in our study. The intake assessment used for this study was adapted from validated questionnaires but has not been validated itself. For example, the questions used to assess food security were not part of a standardized food security assessment. However, the questions that were used are similar to questions used by the USDA ERS to determine the prevalence of food insecurity in the US (Table 1). For instance, our question, “worry about not having enough food to eat,” is similar to many questions asked by the USDA ERS about running out of food.[37] Furthermore, our question, “lack of money keeps me from eating a healthy diet,” is similar to the question “we couldn’t afford to eat balanced meals” asked by the USDA ERS.[37] Another limitation of this study is that much of the data is based on self-reports, which opens up the possibility that an individual may respond how they believe the physician wants them to respond. This also allows for problems with recall and accuracy. In addition, response rates were low for some questions on the intake assessment. The cross-sectional and correlational nature of this study means that cause and effect relationships cannot be determined. However, our data clearly show a relationship between food insecurity and various important factors, such as BMI, depression, anxiety, history of abuse, consumption of SSB and high-fat milk, and importance or value placed on “fullness,” in a population with obesity.

In conclusion, the current study was motivated by our previous research in which we found that those in our weight management clinic with food insecurity were less likely to lose weight. We aimed to determine factors correlated with food insecurity in this population with obesity. We found that those with food insecurity reported differences in habits and consumption patterns, specifically higher consumption of SSB and consumption of higher-fat milk, which could be contributing a substantial number of calories to this population’s diet. Our most

interesting findings are those related to mental health and hunger. In our population with obesity, there were significant differences in mental health between food security groups; those with food insecurity reported higher rates of anxiety, depression, the frequency of depressive symptoms, and history of physical or sexual abuse. Finally, those with food insecurity ranked the importance of having the perception of “feeling full” as much more important to them compared to those without food insecurity, despite those with food insecurity in our clinic population having higher BMIs compared to those who were food secure. We propose the potential for food insecurity in susceptible individuals to contribute to an increase in motivational salience towards food (seen in the importance of feeling full) and an increase in the drive to consume more highly palatable foods (such as SSB or higher fat milk). Further research is needed to better understand these issues in individuals with food insecurity.

Our findings underscore the need for effective multidisciplinary interventions, with adequate attention to psychological factors and food insecurity, to effectively address the obesity epidemic. An effective team including physicians, dietitians, nurses, educators, physical activity trainers, and clinical psychologists and psychiatrists is needed for management of this complex disease state. In addition, it is possible that government health insurance plans, in which many individuals in this population participate, may not be providing adequate care and coverage for the problems this population needs addressed. For example, some Medicaid programs may not cover behavioral weight loss interventions. It is likely that there are changes that could be made at the policy level that would further help those with food insecurity receive proper care. Those with food insecurity face various challenges that put them at a higher risk of obesity and other health conditions. Much more research is needed to better understand this population and how to best provide care to help these individuals improve health risks.

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