Food Insecurity, Ultra-Processed Food Acquisitions/Intake, and Diabetes Risk Factors in U.S. Adolescents Ages 12 – 19 Years

by

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Dedication

This dissertation is dedicated to my mother, father, brother, and all of my family and friends, who have been unwaveringly supportive of me and my goals.

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Abstract

Household food insecurity, a condition of lack of access to sufficient nutritious foods, is a psychological and physiological stressor that has been associated with poor dietary quality and diabetes risk in low-income United States adults. However, research on food insecurity, dietary quality, and diabetes risk factors in adolescents is limited. The evidence base is specifically very limited in relation to ultra-processed foods (UPFs). UPFs are foods that tend to be hyper-palatable, calorie-dense, and nutrient-poor. Their consumption has been associated with diabetes, and recent research shows that UPFs may possess addictive characteristics. Adolescents with food insecurity and their households may be particularly vulnerable to acquisition/purchase and consumption of UPFs which could increase long-term diabetes risk; however, this research area has been insufficiently examined. Provided the numerous potential health consequences of UPFs, this subject bears crucial public health importance. Therefore, this dissertation investigates the association of food insecurity with 1) UPF acquisition/purchase in a national sample of U.S. households with adolescents 2) UPF consumption in lower-income U.S. adolescents and 3) diabetes risk factors in lower-income U.S. adolescents. Associations between Supplemental Nutrition Assistance Program (SNAP) participation with UPF acquisition/purchase and intake are also examined. Data comes from the National Food Acquisitions and Purchasing Survey (FOODAPS) 2012-2013 and the National Health and Nutrition Examination Survey (NHANES) 2007-2016. UPFs are identified through the NOVA classification system. It was found that 1) marginal food security was associated with higher UPF acquisition/purchase for home consumption in U.S. households 2) household SNAP participation was associated with higher

UPF intake in lower-income U.S. adolescents and 3) food insecurity was associated with higher HbA1C in lower-income U.S. adolescents. However, no associations were found between food insecurity and UPF acquisition/purchase for U.S. households with adolescents or for UPF intake in lower-income U.S. adolescents. These findings have important implications for future research and the health of lower-income U.S. adolescents.

Chapter 1 Introduction

1.1 Specific Aims

In the United States, 13.6% of households with children are impacted by food insecurity with non-Hispanic Black and Hispanic households inequitably affected. [1] Household food insecurity has been associated with poor dietary quality [2] and chronic disease risk [3] – including diabetes [4] – in adults with inconsistent evidence in children and adolescents. It is also possible that food insecurity influences the intakes of ultra-processed foods (UPFs).

Food-insecure adolescents might be disproportionately at risk for exposure, purchasing, and intake of UPFs, putting them at higher long-term diabetes risk. For example, research has shown that low-income and racial/ethnic minority adolescents tend to have high exposure [5] to sugar-sweetened beverages (SSBs), that low-income and Non-Hispanic Black households tend to have high levels of SSB purchasing [6], and that Non-Hispanic Black and Hispanic youth tend to have higher intakes of SSBs [7] which can increase long-term diabetes risk. [8] However, no published research has currently studied the associations between food insecurity, overall UPF acquisition/purchasing, UPF intake and diabetes risk in U.S. adolescents.

Therefore, further research on the association between food insecurity, dietary quality, and diabetes risk factors in children and adolescents is warranted. This dissertation focuses on the association between food insecurity, UPF acquisition/purchase, UPF intake (as categorized by the NOVA classification system [9]) and diabetes risk factors in United States adolescents. This research fills a critical gap in the literature by looking specifically at processing level of food and diabetes risk factors in adolescents. This is important because, due to the hyper-

palatable nature of UPFs, [9] food insecurity could significantly impact UPF purchasing/intake [10] compared to other traditionally "unhealthy" foods. This excess consumption of UPFs can then increase diabetes risk due their high-calorie and nutrient-poor characteristics. [9]

1.1.1 Aim 1

Evaluate the association between food insecurity and household UPF acquisition/purchase for home consumption in U.S. households and households with adolescents aged 12 – 19 years using data from the National Food Acquisitions and Purchasing Survey (FOODAPS) 2012 – 2013. It is hypothesized that food insecurity will be associated with higher UPF acquisition/purchase. Additional analysis examines the association between household SNAP participation and UPF acquisition/purchase. It is hypothesized that household SNAP participation will be associated with higher UPF intake.

1.1.2 Aim 2

Evaluate the association between household food insecurity and UPF intake, as measured through the NOVA classification system, in lower-income U.S. adolescents aged 12 – 19 years using data from the National Health and Nutritional Examination Survey (NHANES) 2007 – 2016. It is hypothesized that food insecurity will be associated with higher UPF intake. Additional analysis examines the association between household SNAP participation and UPF intake. It is hypothesized that household SNAP participation will be associated with higher UPF intake.

1.1.3 Aim 3

Evaluate the association between household food insecurity and the diabetes risk factors of fasting blood glucose, oral glucose tolerance, Hemoglobin A1c, homeostatic model assessment –

insulin resistance (HOMA-IR), and triglyceride-to-high density lipoprotein cholesterol ratio (TG/HDL-c) in lower-income adolescents aged 12 – 19 years using data from NHANES 2007 – 2016. The combined association of food insecurity and UPF consumption with the diabetes risk factor levels will also be tested. It is hypothesized that food insecurity will be associated with elevated diabetes risk factors. It is also expected that food-insecure adolescents with high levels of UPF consumption will have higher levels of fasting blood glucose, oral glucose tolerance test (OGTT), Hemoglobin A1C (HbA1C), HOMA-IR, and TG/HDL-c than food-secure adolescents with high UPF consumption and food-insecure adolescents with low UPF consumption.

1.2 Background and significance

Food insecurity – defined as inadequate access to nutritious foods [11] – affects approximately 1 in 10 Americans. [12] In the United States, 13.6% of households with children experience food insecurity; furthermore, female single-parent households, Non-Hispanic Black households, and Hispanic households disproportionately experience food insecurity, [1] demonstrating major inequities. Research has demonstrated that food-insecure households with children tend to have less access to healthy, nutritious foods and more access to fast food. [13] Most low-income communities also have high exposure to cheap processed foods [14] that insufficiently address nutrition and hunger. Thus, it is possible that food insecurity would be associated with higher UPF acquisition/purchasing and intake.

UPFs are defined by the NOVA classification system as: "Formulations of ingredients, mostly of exclusive industrial use, that result from a series of industrial processes (hence 'ultra-processed'), many requiring sophisticated equipment and technology…" [9] This system classifies food into four categories by level of processing: ultra-processed food, processed food, processed culinary ingredients, and unprocessed food. [9] The full NOVA classification system

can be found in Supplemental Table 1 from Monteiro et al. [9] UPFs tend to be hyper-palatable, calorie-dense, and nutrient-poor. [9] They also tend to be high in added sugar, salt, and fat [9] and are less likely to be satiating. [15] For instance, in a randomized controlled trial, research participants that were assigned to an ultra-processed food diet (that had the same macronutrient composition of an unprocessed foods diet), consumed on average 500 calories/day more than the participants on an unprocessed foods diet over a two week period. [16]

Thus, unsurprisingly, UPFs have been associated with numerous deleterious health effects. A systematic review of twenty-six research studies by Costa et al. demonstrated that UPF consumption is associated with adiposity in children and adolescents. [17] UPFs have also been implicated in producing a more extreme glycemic response compared to less processed foods. [15] In adults, Martínez Steele et al. found that UPF consumption is associated with metabolic syndrome [18] and in a longitudinal cohort study, Srour et al. found that UPF consumption was associated with higher diabetes risk. [4] Elizabeth et al. also have found that UPFs are associated with higher diabetes risk. [19] Finally, Kim et al. found that UPF consumption was associated with higher mortality rates in United States adults. [20] Thus, excessive UPF consumption is associated with poor dietary quality, higher adiposity, higher diabetes risk, and higher mortality.

These associations are of high public health importance as approximately 1 in 12 Americans has type 2 diabetes. [21] Furthermore, the rates of diabetes diagnosis in American children and adolescents is increasing [22] and approximately 1 in 5 American adolescents has prediabetes. [22] Type 2 diabetes is a major public health issue as it is associated with higher morbidity due to diabetes complications such as hypertension, retinopathy, neuropathy, and kidney damage [23] and higher mortality as well. [24] In 2017, diabetes cost the United States

$358.9 billion [25] demonstrating the high monetary burden of diabetes on individuals, the healthcare system, and the economy.

Food insecurity has been associated with excessive exposure to traditionally "unhealthy foods" and research has been conducted to evaluate the association between food insecurity and dietary quality. For instance, Gregory et al. found that food insecurity was associated with poor quality food acquisitions as measured through the 2010 Healthy Eating Index (HEI); [26] however, little to no additional research has been conducted specifically on food insecurity and dietary purchasing or acquisitions in the United States. However, multiple studies have found that food insecurity is associated with poor dietary quality in U.S. adults. [27] Leung et al. found that food insecurity was associated with poor dietary quality in low-income adult populations as measured through the 2005 HEI index and the 2010 Alternate Healthy Eating Index (aHEI). [28] Although processing was not examined, food insecurity was associated with higher consumption of SSBs, red/processed meats, and salty snacks. [28]

On the other hand, research on the association between food insecurity and dietary quality in adolescents is varied. Some research suggests an association between food insecurity and poor dietary quality in adolescents [29] while other research indicates less homogenous evidence. [30] For example, Rossen et al. found no evidence of an association between food insecurity and dietary quality in children and adolescents ages 2-15 years unless comparing very low food security individuals with their food-secure peers [31] and Jun et al. found that micronutrient adequacy but not dietary quality as measured through HEI 2015 was positively associated with food security. [32] Meanwhile, in a national sample, Eichner-Miller et al. found that food-insecure children and adolescents were more likely to consume sugar-sweetened beverages. [33] Similarly, Lee et al. found that food insecurity was associated with higher sugar-

sweetened beverage intake and lower fruit consumption on summer weekends in Minnesotan children. [34] Research has also shown that younger populations, low-income populations, Non-Hispanic Black populations, and Hispanic populations have higher intakes of ultra-processed food in the United States. [35] However, this association in food-insecure adolescents has not been sufficiently studied. No research has been conducted on UPF acquisition/purchase patterns in food-insecure U.S. adolescent populations as well.

The current evidence on dietary quality in food-insecure adolescents is limited in terms of information surrounding food acquisitions/purchases. Additionally, the literature could be inconsistent due to the repeated use of a limited number of dietary quality measures (whether an overall dietary index or specific dietary components) that might not consistently capture differences in adolescents' dietary intake. For example, as Hall et al. utilized in their randomized controlled trial, it is possible to have an ultra-processed food diet that is nutritionally equivalent (based on energy density, macronutrients, sodium, sugar, and fiber) to an unprocessed food diet that still promotes excessive caloric intake and weight gain. [16] Particularly provided that younger and low-income U.S. populations tend to have higher intakes of ultra-processed food, [35] as well as newer emerging evidence around higher consumption of specific ultra-processed foods i.e. SSBs, [33], [34], using the NOVA classification system might address both the limited scope and inconsistency of the literature. Therefore, it is imperative to assess the association between food insecurity, UPF acquisition/purchase, and UPF intake in U.S. adolescents. Although numerous studies on food insecurity and dietary quality in U.S. children and adolescents exist, more research on food insecurity and UPF acquisition/purchase and consumption is necessary.

As previously mentioned, food insecurity has been associated with higher diabetes risk in adults. According to Seligman et al., in a national sample of lower-income United States adults, severely food insecure individuals had 2.1 times the risk of diabetes (as measured through elevated fasting blood glucose or self-report) compared to their fully food secure counterparts. [36] Wright et al. similarly found that food insecurity was associated with prediabetes [37] while Liu et al. found that food insecurity was associated with insulin resistance in U.S. adults. [38] In younger adults, food insecurity has also been associated with self-reported diabetes, [39] diabetes and prediabetes as measured through HbA1C, FBG, or diabetes medication status, [40] and diabetes in individuals with obesity that experience very low food security. [41] Furthermore, research has shown that food-insecure individuals that already have diabetes have difficulty managing their glucose levels due in part to diabetes-related emotional distress as well as challenges in "affording a diabetic diet." [42] Thus, the evidence clearly indicates a link between food insecurity and diabetes risk factors in U.S. adults.

Meanwhile, research on food insecurity and diabetes risk in adolescents is exceptionally limited. One study using a national sample found an association between food insecurity and prediabetes risk in U.S. adolescents. [43] Specifically, the authors found that food insecurity in adolescents ages 12 – 19 years was associated with 1.94 higher odds of prediabetes based on HbA1C values. [43] Finally, while research linking food insecurity, UPF intake, and chronic disease in adolescents does not exist, Edalati et al. have shown that adolescent consumption of ultra-processed food is associated with oxidative damage of DNA [44] which might prove detrimental for long-term diabetes risk [45] and other chronic disease risk. [46] More research should be conducted on the association between food insecurity and diabetes risk factors to confirm previous research using multiple measures of diabetes risk (including FBG, OGTT,

HOMA-IR, and TG/HDL-c) as well as assess the possibility of a link between food insecurity, diabetes risk factors, and dietary quality – in particular, UPF consumption.

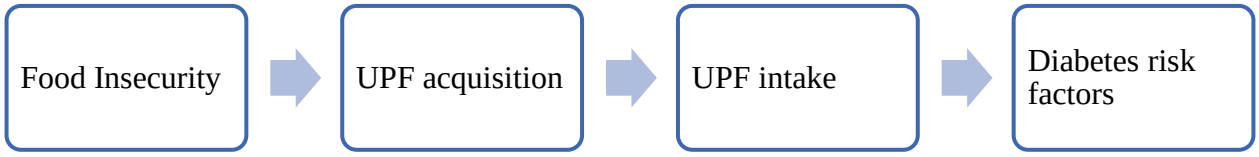

Figure 1: Diagram of postulated association between food insecurity, UPF acquisition/intake, and diabetes risk factors in U.S. adolescents.

This issue has critical public health importance because during adolescence, 1) teenagers are more likely to experience the negative impacts of food insecurity than younger children [47] and 2) teenagers are more likely to make their own food choices than younger children. While chronic disease is unlikely to immediately develop in most adolescents, intake of ultra-processed foods could increase body fat [16] and increase the risk of diabetes in the long-run [19] particularly if food choice and consumption patterns are maintained into adulthood. Furthermore, as teenagers gain independence during adolescence, this could serve as a critical policy and behavioral intervention period to enable food-insecure adolescents to continue developing and maintaining healthy food choices. Therefore, this dissertation will address the associations between food insecurity, UPF acquisition/purchase and intake, and diabetes risk factors in United States adolescents through national datasets.

1.3 Innovation

This dissertation demonstrates innovation through the following: 1) being one of the first major research projects to study UPF acquisition/purchase and intake in food-insecure adolescents 2) being one of the first major research projects to study multiple diabetes risk factors in a food-

insecure U.S. adolescent population and 3) examining the potential link between food insecurity, UPF, and diabetes risk factors in food-insecure adolescents.

Another innovative dimension of this research proposal is the investigation of acquisition/purchase, intake, and chronic disease risk specifically in adolescence, which can serve as a critical intervention period. During adolescence, teenagers gain independence and begin to make their own food choices. In theory, these choice patterns could continue into adulthood and influence subsequent food intake and chronic disease risk. Thus, public health policy interventions surrounding marketing of ultra-processed foods, the National School Lunch Program (NSLP), and the Supplemental Nutrition Assistance Program (SNAP) could alter associations between food insecurity and ultra-processed food acquisition/purchase, intake, and subsequent disease risk in food-insecure adolescents.

1.4 Rationale

Food insecurity is a major issue in the United States that has clear psychological [48] and physiological [49] ramifications. Research has demonstrated associations between food insecurity with poor dietary quality [28] and diabetes risk [36] in U.S. adult populations while research in adolescents is either varied or limited. However, food-insecure adolescents might be at high risk for UPF purchasing, intake, and subsequent disease risk based on research of high UPF consumers [35] and potential health risks of UPFs. [19] Thus, this body of research has substantial public health implications.

This research project would be the first to assess the possible connection between food insecurity, ultra-processed food acquisition/intake, and diabetes risk factors in United States adolescents. The project has many strengths including the use of large national datasets, robust analysis procedures, the use of validated [50] measures of food insecurity, and the use of clinical

biomarkers. This project will contribute to the growing body of research that serves as the basis for evidenced-based food programs and policies to improve adolescent health through addressing dietary behaviors and subsequent chronic disease risk. Ultimately, this research will generate critical information for improving health in U.S. food-insecure adolescents.

Chapter 2 Aim 1: Associations between Food Insecurity and Supplemental Nutrition Assistance Program (SNAP) Participation with Ultra-Processed Food Acquisitions/Purchases for Home Consumption in U.S. Households and U.S. Households with Adolescents

2.1 Abstract

Background: Ultra-processed foods (UPFs) have been shown to be disease-promoting and potentially addictive. However, no research has quantitatively examined UPF acquisitions/purchases by food insecurity and Supplemental Nutrition Assistance Program (SNAP) status in U.S. households.

Objective: This analysis examines the association between food insecurity and SNAP participation with UPF acquisitions/purchases for home consumption in U.S. households and U.S. households with adolescents.

Participants: The sample is 3949 U.S. households from the National Household Food Acquisition and Purchase Survey (FOODAPS). A sub-sample of 1006 U.S. households with adolescents is also examined.

Methods: Food insecurity was assessed through the 10-item Adult Food Security Survey Module. Household SNAP participation was considered affirmative if any member of the household reported receiving SNAP benefits. Household UPF acquisitions/purchases for home consumption (as a percentage of total energy acquired/purchased) were determined by the NOVA classification system. Multivariable linear regressions that adjusted for household sociodemographic characteristics quantified the associations between food insecurity and SNAP

participation with UPF acquisitions/purchases for home consumption in U.S. households and U.S. households with adolescents.

Results: 15.5% and 13.9% of U.S. households experienced marginal food security and food insecurity, respectively. 21.2% and 19.2% of U.S. households with adolescents experienced marginal food security and food insecurity, respectively. Adjusted means for UPF acquisition/purchase for home consumption across food security and SNAP categories were high, ranging from 53.2% to 57.0% in U.S. households and 62.9% to 67.6% in U.S. households with adolescents. Among all US households, marginal food security was associated with 3.85% higher UPF acquisitions/purchases for home consumption ($p = 0.004$) compared to households with high food security; however, there was no association for SNAP. In U.S. households with adolescents, there were no associations for food insecurity and SNAP participation with UPF acquisitions/purchases.

Conclusions: UPF acquisitions/purchases for home consumption are high for U.S. households and households with adolescents across food security and SNAP categories. Additionally, marginal food security is associated with higher UPF acquisitions/purchases for home consumption in U.S. households. More research on the drivers of this association should be conducted. Strategies that facilitate acquisitions/purchases of unprocessed and minimally processed foods for all U.S. households could improve dietary intake and subsequent health.

2.2 Introduction

Food insecurity, a state of inconsistent or inadequate access to sufficient food, [11] impacts approximately 1 in 10 U.S. households. [12] In U.S. adults, food insecurity has been associated with poor dietary intake, [2] cardiovascular disease, [51] and diabetes. [36] In U.S.

children and/or adolescents, it has been associated with mental health disorders, [52] higher intake of sugar-sweetened beverages [53] [34] and fast food, [53] and prediabetes risk. [43]

The Supplemental Nutrition Assistance Program (SNAP) – a federal nutrition assistance program [54] - has been shown to improve food security [55] because it provides benefits to program participants to purchase additional food. [54] However, a cost analysis determined that SNAP benefits are likely not enough to facilitate healthy consumption patterns; [56] as a result, SNAP participation has been associated with lower quality food purchases. [57] It has also been associated with poor dietary intake in U.S. adults [58] and children. [59] Finally, SNAP participation has been associated with negative cardiometabolic outcomes in both U.S. adults [60] and adolescents. [61]

Recent evidence has shown that food insecurity and SNAP participation is associated with higher intake of ultra-processed foods (UPFs) in lower-income U.S. adults. [62] Similarly, new research has shown some evidence for an association between food insecurity and higher intake of certain UPF items in U.S. children and/or adolescents. [34, 53] UPFs are a public health concern because of their low nutritional value [63] and their association with cardiovascular disease, [64] diabetes, [65] and cancer. [66]

However, no research has quantitatively examined the associations between food insecurity and SNAP participation with UPF acquisitions/purchases, a potential facilitator of high intake. For example, it is unknown if one of the reasons for high UPF intake in lower-income individuals with food insecurity and/or SNAP participation is higher household acquisitions/purchases of UPFs. This information could enable the development of interventions at appropriate points on the pathways between food insecurity and SNAP participation with

higher UPF intake. Finally, this knowledge could inform evidence-based improvements to current nutrition policies and programs.

Therefore, this paper examines the association between food insecurity and household SNAP participation with household UPF acquisitions/purchases for home consumption for 3949 U.S. households and 1006 U.S. households with adolescents using data from the 2012 – 2013 National Household Food Acquisition and Purchase Survey. [67] It is hypothesized that both food insecurity and household SNAP participation will be associated with higher household UPF acquisitions/purchases for home consumption for both sets of households.

2.3 Methods

2.3.1 Dataset

The data came from the United States Department of Agriculture (USDA) National Household Food Acquisition and Purchase Survey (FOODAPS). This national, cross-sectional, complex survey was administered in 2012 – 2013 and contains data from 4,826 U.S. households. [67] Survey participants are asked to record their food acquisitions and purchases for seven days. Information is collected on food items, groups of acquisitions/purchases (transactions), individuals, and households. Additionally, the survey asks about food security, federal nutrition assistance program participation, sociodemographic characteristics, and more. [67] The primary household respondent – the household member most responsible for food shopping and/or meal planning – provided the latter information on behalf of the household. [67]

2.3.2 Sample

The sample consists of 3949 U.S. households that had non-missing information on food acquisitions/purchases, food insecurity, household SNAP participation, and other variables of

interest. A sub-sample of 1006 U.S. households with adolescents aged 12 – 19 years was also constructed. Households were excluded from the sample if they were missing food-at-home (FAH) data, reported fewer than 6 or greater than 150 FAH items, reported insufficient item data, or reported excessive total energy acquired/purchased for home consumption. This criteria was used previously for a similar analysis. [68]

2.3.3 Exposures

The exposure of food insecurity was assessed through the USDA 30-Day Adult Food Security Survey Module. [69] The primary household respondent answered the 10-item survey. Affirmative responses to 0, 1-2, 3-5, or 6+ questions were coded as high food security, marginal food security, low food security, or very low food security, respectively. [67] For this analysis, the categories of low and very low food security were conjoined to create a "food insecurity" category. The exposure of household SNAP participation was deemed affirmative if one or more household members reported receipt of SNAP benefits. [67]

2.3.4 Outcome

The outcome variable was household UPF acquisitions/purchases for home consumption as a percentage of total household energy purchased/acquired for home consumption. To calculate this variable, FOODAPS FAH acquisition/purchase data [67] were used to determine the food items acquired/purchased for each household. Food items were classified as UPFs or non-UPFs by their food codes or standard reference (SR) codes through the NOVA classification system. [9] Additional research provides information on the previous application of the NOVA classification to FOODAPS data. [68] The energy (in kilocalories) of the food items was calculated by using the edible weight of food (in grams) acquired/purchased. For relevant food

items, values imputed by the Economic Research Service (ERS) for weight of food in grams [67] were used. The energy content of the UPF items were aggregated by household to create household UPF kilocalories acquired/purchased for home consumption. This number was then divided by total household energy acquired/purchased (for home consumption) to generate the outcome variable.

2.3.5 Covariates

The covariates were: age (in categories), sex (male/female), race/ethnicity, marital status, and education status of the primary household respondent; household income-to-poverty ratio and household size. Race/ethnicity was coded as the following categories: non-Hispanic White, non-Hispanic Black, Hispanic ethnicity, and other non-Hispanic race. Marital status was a binary variable of "married" or "not married." The education status variable consisted of two categories: less than high school graduate and high school graduate. Household income-to-poverty ratio is a variable calculated by FOODAPS through the division of household income by the federal poverty guideline. [67] Finally, household size is the number of non-guest individuals in the household. [67]

2.3.6 Statistical Analysis

Weighted means and proportions were calculated for the descriptive statistics. Rao-Scott Chi-square tests and simple linear regressions were conducted for categorical and continuous variables, respectively. Multivariable linear regressions evaluated the association between food insecurity and SNAP participation with UPF acquisitions/purchases in the main analyses. Model 1 was adjusted for primary household respondent age and sex, household size, and total energy acquired/purchased for home consumption. Model 2 was adjusted for all covariates and the

SNAP analyses were further adjusted for food insecurity status. FOODAPS household weights, strata, and clustering [67] were applied for all analyses using survey procedures in SAS Version 9.4 (Cary, NC). An alpha level of 0.05 was used to determine statistical significance.

2.4 Results

In the U.S., 15.5% of households experienced marginal food security and 13.9% experienced food insecurity. In U.S. households with adolescents, 21.2% experienced marginal food security and 19.2% experienced food insecurity. In U.S. households, food insecurity was associated with lower household respondent age ($p < 0.0001$), education ($p < 0.0001$), and household income-to-poverty ratio ($p < 0.0001$). It was also associated with non-Hispanic Black race, Hispanic ethnicity, and other non-Hispanic race for the primary household respondent ($p < 0.0001$), "not married" primary household respondent status ($p < 0.0001$), larger household size ($p < 0.0001$) and household SNAP participation ($p < 0.0001$) (Table 1). The associations between food insecurity and covariates were similar for U.S. households with adolescents except for the association with household size, which was marginally statistically significant ($p = 0.08$) (Table 2).

Across the food security and SNAP participation spectrum, adjusted mean UPF acquisitions/purchases for home consumption as a percentage of total energy acquired/purchased were high for U.S. households and U.S. households with adolescents, ranging from 53.2% to 67.6%. For U.S. households, the Model 1 food insecurity analysis showed an association between marginal food security and 4.55 % higher household UPF acquisition/purchase for home consumption as a percentage of total energy acquired/purchased ($p = 0.0003$). There was also an association between food insecurity and 2.99% higher UPF acquisition/purchase ($p = 0.03$). The p-for-trend for this association was statistically significant ($p = 0.004$). After

multivariable adjustment, the Model 2 analysis demonstrated an association between marginal food security and 3.85% higher UPF acquisition/purchase ($p = 0.004$) and there was no longer an association for food insecurity ($p = 0.18$). The p-for-trend for this association was marginally statistically significant ($p = 0.07$) (Table 3). The Model 1 SNAP analysis showed an association between household SNAP participation and 3.84% higher UPF acquisition/purchase ($p = 0.002$); however, after multivariable adjustment, the Model 2 analysis demonstrated no association ($p = 0.32$) (Table 5).

For U.S. households with adolescents, the Model 1 analysis of food insecurity demonstrated a marginally statistically significant association for marginal food security and 4.20% higher UPF acquisition/purchase ($p = 0.07$); however, this association was fully attenuated in Model 2 ($p = 0.21$) (Table 4). There were no other associations between food security status or household SNAP participation with UPF acquisition/purchase (Table 6).

2.5 Discussion

Within this sample of U.S. households, the averages for household UPF acquisitions/purchases intended for home consumption were high across food security and household SNAP participation categories. Overall, marginal food security was associated with higher UPF acquisition/purchase; however, there was no association between household SNAP participation with UPF acquisition/purchase. For U.S. households with adolescents, no associations between food insecurity and household SNAP participation with UPF acquisition/purchase were found.

This paper is the first to quantitatively examine the associations between food insecurity and SNAP participation with UPF acquisitions/purchases for home consumption in U.S. households. Very few studies have examined the association between food insecurity and the

nutritional quality of food acquired/purchased. Gregory et al. used FOODAPS data to determine that households with food insecurity were likely to purchase more refined grains and less fruit, dairy, and protein. [26] For households with children, reduced food security is associated with a home food environment with more microwaveable or convenience frozen food items [70] which are likely to classified as UPFs. Finally, Vadiveloo et al. found that the nutritional quality of dietary acquisitions/purchases for home consumption was lower in households that participated in SNAP and experienced food insecurity. [71] These results somewhat align with our finding that U.S. households with marginal food security are more likely to acquire/purchase UPFs for home consumption. Additionally, it is possible that results vary slightly between studies because different nutrition constructs are used – e.g. nutrients, food groups, or UPF acquisition/purchase.

With regard to rationale, it is possible that households with marginal food security acquire/purchase more UPFs for home consumption for financial reasons. In fact, research should investigate if these households utilize acquisition/purchase of cheaper UPFs to fend off food insecurity. Meanwhile, households with food insecurity did not have higher acquisition/purchase of UPFs for home consumption. If future research shows that UPF acquisition/purchase for home consumption is a strategy to reduce food insecurity, then by comparison, it would be expected that households with food insecurity would not have higher UPF acquisition/purchase.

Meanwhile, ample literature on the association between SNAP participation and acquisitions/purchases exists. One study found that SNAP participation is associated with acquisitions of lower nutritional quality [72] and another found that it was associated with higher purchases of sugar-sweetened beverages, processed meat, and sweeteners and toppings with lower purchases of fruit and salty snacks. [57] Another report found no major differences in food

item purchases between SNAP and non-SNAP households with the exception of soft drinks, of which SNAP households purchased slightly more. [73] Meanwhile, Chen et al. used FOODAPS data to examine food purchased for home consumption in low-income households and found that SNAP participation was associated with less healthy purchases for households that were deemed "less nutrition-oriented" but not for households that were deemed "nutrition-oriented." [74] Basu et al. used FOODAPS data to determine that SNAP participation was associated with better quality acquisitions in counties with high cost-of-living. [75] For our sample, although the minimally adjusted analyses produced an association, the link between SNAP and UPF acquisition/purchase for home consumption disappeared after multivariable adjustment. The adjustment for food security status – included in the model as a potential confounder – may have played a role in this attenuation. In general, it seems that the evidence for SNAP is somewhat mixed and that associations may vary based on household characteristics and local factors.

Nonetheless, an association between marginal food security and higher UPF acquisition/purchase is concerning. High UPF acquisition/purchase for home consumption in households with marginal food security is a likely contributor to the adjusted mean UPF intake of 53.6% (as a percentage of total energy intake) [62] in lower-income adults with marginal food security. High UPF intake is detrimental to health due to its long-term association with cardiovascular disease, [64] diabetes, [65] and cancer. [66] Additionally, provided the potentially addictive qualities of UPFs [76] and association with binge eating, [77] the inequitable exposure of marginally food secure households to this class of foods is particularly troubling.

In addition to examining the association between marginal food security and higher household UPF acquisition/purchase for home consumption, it is important to examine the other study findings within the broader backdrop of literature on UPF intake, as some key distinctions

appear. Very low food security is associated with 3.1% higher UPF intake and SNAP participation was associated with 1.7% higher UPF intake in lower-income U.S. adults. [62] While marginally food secure households are more likely to acquire/purchase UPFs for home consumption, lower-income adults with food insecurity are more likely to consume UPFs. [62] Additionally, while no associations were found for household SNAP participation and UPF acquisition/purchase, lower-income adults from households that participate in SNAP were more likely to consume UPFs. [62]

The differential findings between UPF acquisition/purchase and intake raise some important considerations. To begin, it points to the difference between acquisition/purchase and consumption. Generally, the acquisition/purchase of a food item may not correlate exactly with consumption. While fresh foods can go to waste and thus be consumed less, ultra-processed foods are generally shelf-stable and could be consumed more. Individuals on SNAP have reported preference for UPFs for their shelf-stable qualities. [78] Individuals on SNAP also tend to select UPFs because they require minimal preparation and household children are likely to consume them (and decrease likelihood of food waste). [78] It is possible that individuals with food insecurity choose UPFs for similar reasons but that has not been examined in the literature – however, this qualitative study did indicate that some SNAP participants would buy and store UPFs in an attempt to reduce the risk of food insecurity later in the month. [78] Therefore, though food insecurity and SNAP participation are not associated with higher UPF acquisition/purchase for home consumption, disproportionately high consumption of available UPFs could occur in lower-income U.S. adults with food insecurity or SNAP participation due to long shelf-life, which enables UPFs to persist as a food option even when other food supplies may run low, lower preparation requirements, or other reasons. Overall, the findings suggest that

factors such as constraints within the home (such as time or money) or food acquired/purchased outside the home may drive high UPF intake in lower-income U.S. adults with food insecurity or SNAP participation. The results also show that all households could benefit from a reduction in UPF acquisition/purchasing for home consumption, especially households with marginal food security.

Consequently, future research should examine mechanisms for higher UPF acquisition/purchase and intake in lower-income populations that have less food security or participate in SNAP. For example, qualitative work should be conducted with marginally food secure households to see what drives higher UPF acquisition/purchase for home consumption in that group (and if it becomes a coping strategy to maintain food security status). Focus groups for individuals that are food insecure could examine reasons for higher UPF intake in this population. Moran et al. has examined drivers of UPF purchases and intake in SNAP households with children [78] and this work could be expanded to include all SNAP households. A quantitative analysis on the association between food insecurity and SNAP participation with UPF acquisition/purchase outside the home (such as fast food places, restaurants, etc.) would also shed light on this issue. Understanding these mechanisms could provide the basis for critical public health interventions.

Depending on underlying mechanisms, a suite of public health interventions across the socioecological model could be tested and tailored to address higher UPF acquisition/purchase and intake for lower-income families that lack full food security or participate in SNAP. For example, higher SNAP benefits could enable the purchase of healthier food items and a higher quality diet. [79] Programs that incentivize fruit and vegetable purchases have been shown to improve purchasing and dietary quality in SNAP participants [80] and thus, the potential for this

intervention to improve UPF purchasing/intake in lower-income families that lack full food security or participate in SNAP could be investigated. Research has shown that product placement and promotion are associated with purchases [81]; therefore, perhaps local government and non-profits could provide incentives for supermarkets and grocery stores to promote non-UPF items. Researchers could conduct a pilot study to see if improving the availability of unprocessed foods (or premade meals based on unprocessed foods) at local religious, non-profit, and hunger relief organizations could improve UPF acquisition and intake. Finally, broader social and economic policies that improve finances and time scarcity [82] would likely improve a lower-income household's ability to acquire/purchase unprocessed foods and prepare more nutritious meals (as well as decrease fast food consumption).

This study has multiple strengths. To start, it uses data that is nationally representative. Also, the food-at-home acquisition/purchase data may be less susceptible to recall bias than dietary intake data due to additional reliance on receipts and barcodes. [67] One of the main limitations of the analysis is the cross-sectional data collection which can lessen the ability to infer causality. However, it is likely that acquisitions/purchases are result of food security status and/or household SNAP participation rather than the opposite, so reverse causality is relatively unlikely. As always, reporting bias may be an issue for variables such as food security status, household SNAP participation, and income, due to their private nature. [83] However, FOODAPS takes measures to account for non-response bias and methods are used to obtain the most accurate data possible. [67] Another limitation is that the food security status of the household respondent was utilized as a proxy measure for that of the household. Particularly for U.S. households with adolescents, food security status of the household respondent may differ from other members in the household. Furthermore, the 30-day measure might not be

representative of long-term food security status or sporadic periods of food insecurity. However, FOODAPS does not provide a twelve month measure of household food security [67] so the best available measure was used. Finally, the possibility of residual confounding cannot be excluded. Even with the limitations, this paper addresses a critical gap in the evidence base and is the first quantitatively examine UPF acquisition/purchase for home consumption in households with decreased food security and households that participate in SNAP.

To conclude, household UPF acquisition/purchase for home consumption was high for U.S. households and U.S. households with adolescents with varying levels of food security and SNAP participation status. Marginal food security was associated with higher levels of UPF acquisition/purchase for home consumption; these high levels of UPFs in the home environment very likely contribute to UPF intake in this population, which is concerning due to the many negative health effects of UPFs. [64] [65] [66] Research on the driving factors creating high acquisition/purchase of UPFs in this group should be examined and evidence-based interventions to improve unprocessed food acquisition/purchasing in this group should be implemented. Although food insecurity and household SNAP participation are associated with higher UPF intake in lower-income U.S. adults, there was no evidence that food insecurity or household SNAP participation are associated with higher UPF acquisition/purchase for home consumption. Therefore, research should be conducted to assess alternative drivers of high UPF intake in these groups, such as UPF acquisition/purchase outside the home, a reliance on UPFs when other food options run low, or limitations around meal preparation feasibility. Subsequent evidence-based interventions to improve the associations should then be created. Finally, wide-ranging economic and social policies that improve time scarcity [82] and finances for low-income households will likely alleviate the key issues around reduced food security, SNAP participation, UPF

acquisition/purchase, and high UPF intake in these populations. Generally, all U.S. households would benefit from lower UPF acquisition/purchase, lower UPF intake, and better nutrition.

2.6 Tables

Table 1: Associations between food insecurity and sociodemographic characteristics in U.S. households (n = 3949) from FOODAPS 2012 - 2013

	Overall sample weighted % or mean	N or weighted SE	Full food security weighted % or mean	N or weighted SE	Marginal food security weighted % or mean	N or weighted SE	Food insecurity weighted % or mean	N or weighted SE	*P-value*
Overall (%)	100	3949	70.6	2103	15.5	808	13.9	1038	
Household respondent age (%)									**<.0001**
16 - 19 years	0.4	38	0.4	22	0.3	4	0.6	12	
20 - 35 years	21.6	1166	19.5	550	25.6	274	27.7	342	
36 - 59 years	47.0	1849	45.3	919	48.9	375	53.2	555	
60+ years	31.0	896	34.8	612	25.2	155	18.5	129	
Male household respondent (%)	29.9	968	31	554	26.1	173	28.1	241	0.20
Household respondent race/ethnicity (%)									**<.0001**
Non-Hispanic White	70.3	2392	77.8	1463	55.1	409	49.3	520	
Non-Hispanic Black	9.9	463	7.1	183	15.9	133	17.6	147	
Hispanic ethnicity	12.9	795	8.5	300	21.9	202	25.5	293	
Other non-Hispanic race	6.8	299	6.6	157	7.1	64	7.7	78	
Household respondent education ≥ high school graduate (%)	66.5	2166	72.8	1328	57	401	45.2	437	**<.0001**
Household respondent married (%)	48.0	1808	53.2	1124	38.9	321	31.8	363	**<.0001**
Household income-to-poverty ratio, mean (SE)	375.0	12.8	440.0	14.3	263.63	12.0	169.8	8.0	**<.0001**
Household size, mean (SE)	2.5	0.0	2.4	0.0	2.8	0.1	2.7	0.1	**<.0001**
Household SNAP participation (%)	11.5	1149	5.6	351	16.6	291	35.6	507	**<.0001**

Statistically significant estimates at alpha = 0.05 are bolded.
All analyses used survey procedures that accounted for the complex survey design strata, cluster, and weights.
Simple linear regressions were used for continuous variables and Rao-Scott Chi-square tests were used for categorical variables.
Abbreviations:
FOODAPS = National Household Food Acquisition and Purchase Survey
SE = standard error
SNAP = Supplemental Nutrition Assistance Program

Table 2: Associations between food insecurity and sociodemographic characteristics in U.S. households with adolescents (n = 1006) from FOODAPS 2012 - 2013

	Overall sample weighted % or mean	N or weighted SE	Full food security weighted % or mean	N or weighted SE	Marginal food security weighted % or mean	N or weighted SE	Food insecurity weighted % or mean	N or weighted SE	*P-value*
Overall (%)	100	1006	59.7	420	21.2	242	19.2	344	
Household respondent age (%)									**0.04**
16 - 19 years	2.4	38	2.9	22	1.1	4	2.4	12	
20 - 35 years	15.4	211	11.6	64	21.1	61	20.8	86	
36 - 59 years	77.7	704	81.3	311	71.3	160	73.4	233	
60+ years	4.5	53	4.2	23	6.4	17	3.4	13	
Male household respondent (%)	19.8	177	19.0	72	20.3	46	21.5	59	0.89
Household respondent race/ethnicity (%)									**<.0001**
Non-Hispanic White	60.0	480	68.3	237	53.8	102	41.3	141	
Non-Hispanic Black	11.0	129	8.9	48	11.7	38	16.8	43	
Hispanic ethnicity	21.5	323	15.7	106	26.3	84	34.3	133	
Other non-Hispanic race	7.4	74	7.1	29	8.2	18	7.5	27	
Household respondent education ≥ high school graduate (%)	62.8	494	72.0	251	52.0	104	46.1	139	**<.0001**
Household respondent married (%)	61.4	542	69.1	258	51.8	129	48.2	155	**0.0005**
Household income-to-poverty ratio, mean (SE)	323.6	16.5	406.6	22.3	237.7	18.4	160.0	12.2	**<.0001**
Household size, mean (SE)	4.3	0.1	4.1	0.1	4.4	0.2	4.5	0.1	0.08
Household SNAP participation (%)	15.2	356	8.7	102	16.7	92	34.1	162	**<.0001**

Statistically significant estimates at alpha = 0.05 are bolded.
All analyses used survey procedures that accounted for the complex survey design strata, cluster, and weights.
Simple linear regressions were used for continuous variables and Rao-Scott Chi-square tests were used for categorical variables.
Abbreviations:
FOODAPS = National Household Food Acquisition and Purchase Survey
SE = standard error
SNAP = Supplemental Nutrition Assistance Program

Table 3: Associations between food insecurity and household ultra-processed food acquired/purchased (as a percentage of total energy acquired/purchased) for home consumption in U.S. households (n = 3949) from FOODAPS 2012 - 2013

	Model 1					Model 2				
	Adjusted Mean	Estimate	95% CI LL	95% CI UL	P-value	Adjusted Mean	Estimate	95% CI LL	95% CI UL	P-value
Full food security	55.4	Ref.				53.2	Ref.			
Marginal food security	60.0	4.55	2.25	6.85	**0.0003**	57.0	3.85	1.33	6.36	**0.004**
Food insecurity	58.4	2.99	0.34	5.65	**0.03**	55.3	2.11	-1.04	5.26	0.18
P-for-trend					**0.004**					0.07

Statistically significant estimates at alpha = 0.05 are bolded.
All analyses used survey procedures that accounted for the complex survey design strata, cluster, and weights.
Multivariable linear regressions were used to calculate beta coefficient estimates and adjusted means.
Model 1 is adjusted for household respondent age, household respondent sex, household size, and total energy acquired/purchased.
Model 2 is adjusted for Model 1 + household respondent race/ethnicity, education, marital status, and household income (as a quadratic expression)
Abbreviations:
CI = confidence interval
FOODAPS = National Household Food Acquisition and Purchase Survey
LL = lower limit
UL = upper limit

Table 4: Associations between food insecurity and household ultra-processed food acquired/purchased (as a percentage of total energy acquired/purchased) for home consumption in U.S. households with adolescents (n = 1006) from FOODAPS 2012 - 2013

	Model 1					Model 2				
	Adjusted Mean	Estimate	95% CI LL	95% CI UL	P-value	Adjusted Mean	Estimate	95% CI LL	95% CI UL	P-value
Full food security	65.7	Ref.				64.5	Ref.			
Marginal food security	69.9	4.20	-0.30	8.70	0.07	67.6	3.11	-1.83	8.04	0.21
Food insecurity	64.4	-1.29	-5.58	3.00	0.54	62.9	-1.60	-5.92	2.73	0.46
P-for-trend					0.98					0.74

Statistically significant estimates at alpha = 0.05 are bolded.
All analyses used survey procedures that accounted for the complex survey design strata, cluster, and weights.
Multivariable linear regressions were used to calculate beta coefficient estimates and adjusted means.
Model 1 is adjusted for household respondent age, household respondent sex, household size, and total energy acquired/purchased.
Model 2 is adjusted for Model 1 + household respondent race/ethnicity, education, marital status, and household income (as a quadratic expression)
Abbreviations:
CI = confidence interval
FOODAPS = National Household Food Acquisition and Purchase Survey
LL = lower limit
UL = upper limit

Table 5: Associations between SNAP participation and household ultra-processed food acquired/purchased (as a percentage of total energy acquired/purchased) for home consumption in U.S. households (n = 3949) from FOODAPS 2012 - 2013

	Model 1					Model 2				
	Adjusted Mean	Estimate	95% CI LL	95% CI UL	P-value	Adjusted Mean	Estimate	95% CI LL	95% CI UL	P-value
SNAP non-participation	55.9	Ref.				54.9	Ref.			
SNAP participation	59.8	3.84	1.53	6.14	**0.002**	56.4	1.50	-1.50	4.49	0.32

Statistically significant estimates at alpha = 0.05 are bolded.
All analyses used survey procedures that accounted for the complex survey design strata, cluster, and weights.
Multivariable linear regressions were used to calculate beta coefficient estimates and adjusted means.
Model 1 is adjusted for household respondent age, household respondent sex, household size, and total energy acquired/purchased.
Model 2 is adjusted for Model 1 + household respondent race/ethnicity, education, marital status, household income (as a quadratic expression), and food insecurity status.
Abbreviations:
CI = confidence interval
FOODAPS = National Household Food Acquisition and Purchase Survey
LL = lower limit
SNAP = Supplemental Nutrition Assistance Program
UL = upper limit

Table 6: Associations between SNAP participation and household ultra-processed food acquired/purchased (as a percentage of total energy acquired/purchased) for home consumption in U.S. households with adolescents (n = 1006) from FOODAPS 2012 - 2013

	Model 1					Model 2				
	Adjusted Mean	Estimate	95% CI LL	95% CI UL	P-value	Adjusted Mean	Estimate	95% CI LL	95% CI UL	P-value
SNAP non-participation	66.5	Ref.				65.3	Ref.			
SNAP participation	65.4	-1.08	-5.01	2.84	0.58	64.3	-1.00	-5.13	3.13	0.63

Statistically significant estimates at alpha = 0.05 are bolded.
All analyses used survey procedures that accounted for the complex survey design strata, cluster, and weights.
Multivariable linear regressions were used to calculate beta coefficient estimates and adjusted means.
Model 1 is adjusted for household respondent age, household respondent sex, household size, and total energy acquired/purchased.
Model 2 is adjusted for Model 1 + household respondent race/ethnicity, education, marital status, household income (as a quadratic expression), and food insecurity status.
Abbreviations:
CI = confidence interval
FOODAPS = National Household Food Acquisition and Purchase Survey
LL = lower limit
SNAP = Supplemental Nutrition Assistance Program
UL = upper limit

Chapter 3 Aim 2: Associations between Food Insecurity and Supplemental Nutrition Assistance Program (SNAP) Participation with Ultra-Processed Food Intake in Lower-Income U.S. Adolescents

3.1 Abstract

Background: Ultra-processed foods (UPFs) have been shown to have negative health consequences and potentially addictive qualities. Research has shown that UPF intake is higher in adults experiencing food insecurity and participating in the Supplemental Nutrition Assistance Program (SNAP). However, although U.S. adolescents are high consumers of UPFs, the association between food insecurity and SNAP with UPF intake has not been studied in this population.

Objective: This study examines the association between food insecurity and SNAP participation with UPF intake in lower-income U.S. adolescents.

Participants: The participants are 3067 U.S. adolescents aged 12-19 years with household incomes at or below the 300% of the federal poverty line from the 2007-2016 National Health and Nutrition Examination Survey (NHANES).

Methods: Ultra-processed food is defined using the NOVA classification system and measured as a percentage of total energy intake (TEI). Household food security was measured through the U.S. Department of Agriculture 18-Item Household Food Security Survey Module. SNAP participation was deemed affirmative if the household reported receiving SNAP benefits in the last year. Multivariable linear regressions that accounted for the complex survey design were used to examine the associations between food insecurity and SNAP participation with UPF

intake. Analyses controlled for TEI and sociodemographic covariates. All analyses were conducted using SAS Version 9.4.

Results: In the sample, the prevalence of marginal food security was 15.9% and the prevalence of food insecurity was 33.8%. UPF intake ranged from 63.2% to 65.9% across levels of food security and SNAP participation. Food insecurity was not significantly associated with UPF intake. However, SNAP participation was associated with 2.7% higher UPF intake ($p = 0.04$, 95% CI: 0.1%, 5.2%).

Conclusions: In this national sample of lower-income U.S. adolescents, food insecurity was not associated with UPF intake. However, SNAP participation was associated with a higher intake of UPFs. Particularly given the negative health consequences of UPFs, current nutrition programs and policies should be improved to promote the intakes of more healthful, minimally processed foods.

3.2 Introduction

Ultra-processed foods (UPFs) are defined as "formulations of ingredients, mostly of exclusive industrial use, that result from a series of industrial processes." [9] UPFs tend to be high in sodium, sugar, and saturated fat. [9] Additionally, they have been shown to increase calorie intake [16] and are hyper-palatable. [9] UPFs have several negative health implications. In adults, UPF intake has been associated with increased risks of cardiovascular disease, [84] type 2 diabetes, [65] and cancer. [66] In adolescents, UPF intake has been associated with higher adiposity. [85]

UPFs are ubiquitous in the national food supply. For U.S. adults, on average, 55.4% of total energy intake comes from UPFs. [86] For U.S. adolescents, average UPF consumption is even higher, at 67.7%. [87] Recent evidence suggests that certain sociodemographic

characteristics such as education [88] and race [87] are associated with UPF intake. Furthermore, a recent study showed that two sociodemographic characteristics related to food access – 1) food insecurity status and 2) Supplemental Nutrition Assistance Program (SNAP) participation – have been associated with higher UPF intake in lower-income U.S. adults. [62] However, the association between food insecurity and SNAP participation with UPF intake in U.S. adolescents has not been sufficiently examined.

Food insecurity, defined as "a household-level economic and social condition of limited or uncertain access to adequate food," [11] has been associated with 3.1% higher UPF intake in a national sample of lower-income U.S. adults when comparing full food security to very low food security. [62] In general, it has been associated with poor dietary quality in lower-income U.S. adults. [2] [89] Initial evidence on food insecurity and dietary quality in U.S. adolescents was scarce but indicated possible associations. [29] A 2020 review on this age group suggests that food insecurity might be associated with higher intakes of certain food groups, such as sugar-sweetened beverages and fast food, which could be classified as ultra-processed. [90]

The Supplemental Nutrition Assistance Program (SNAP) is an important federal safety-net program that enables lower-income Americans to access sufficient foods. [54] However, even with SNAP benefits, healthy foods are expensive and SNAP participants are more likely to prioritize purchases of low-cost, shelf-stable foods of lower nutritional quality. [91] [71] Subsequently, participation in SNAP has been associated with 1.7% higher UPF intake [62] and poor dietary quality [92] in U.S. adults. For U.S. adolescents, evidence indicates that SNAP is associated with poorer dietary intake. [59, 61, 93] However, no research has conducted a thorough quantitative analysis of the association between household food insecurity and SNAP participation with UPF intake in U.S. adolescents.

Thus, this paper examines the association between household food insecurity and SNAP participation with UPF intake in a national sample of lower-income (300% federal poverty line or below) U.S. adolescents aged 12-19 years from the 2007-16 National Health and Nutrition Examination Survey (NHANES). This paper is one of the first to examine these associations within the context of UPF intake. This is an important innovation because UPF intake might more accurately capture certain foods that are overconsumed. For example, due to the top-coding of the added sugars component in the Healthy Eating Index (HEI) 2015, it might not sufficiently distinguish between plain milk and sugar-sweetened flavored milk. [94] For this study, it is hypothesized that household food insecurity and household SNAP participation will both be associated with higher adolescent UPF intake.

3.3 Methods

3.3.1 Data source

The data were obtained from NHANES, a nationally representative, complex, continuous cross-sectional survey that releases data on demographic information, dietary intake, and health in 2-year cycles. [95] This paper uses data from 2007 – 2016.

3.3.2 Participants

The participants were 3067 lower-income (300% federal poverty line or below) U.S. adolescents aged 12 – 19 years. Participants were included if they had information on the exposures, outcome, and covariates of interest.

3.3.3 Exposures

The exposures were household food insecurity and household Supplemental Nutrition Assistance Program (SNAP) participation. Food security status was determined by the United States Department of Agriculture (USDA) 18-item Household Food Security Survey Module. Households were classified as experiencing full food security (0 affirmative responses), marginal food security (1-2 affirmative responses), low food security (3-7 affirmative responses), or very low food security (8-18 affirmative responses). [69] For this analysis, low food security and very low food security were grouped together to form a food-insecure category. Household SNAP participation was deemed affirmative if anyone in the household had reported receiving SNAP benefits in the past 12 months. [95]

3.3.4 Outcome

The outcome was ultra-processed food (UPF) intake as a percentage of total energy intake (TEI). The NOVA classification system [9] was used to classify foods as UPFs or non-UPFs. This system has been previously applied to NHANES data with methods provided. [96] In brief, NHANES collects dietary data through 24-hour dietary recalls that provide detailed information on the food items consumed. [95] The NHANES dietary data were linked to the USDA's Food and Nutrient Database for Dietary Studies (FNDDS) data [97] by food codes. The FNDDS data contains food codes and standard reference (SR) codes, and a re-merging process had been applied to this dataset to disaggregate the food items into their underlying food codes and SR codes. Based on the descriptions provided for FNDDS food codes and SR codes, food items were classified as UPFs or non-UPFs. Then, UPF intake as a percentage of TEI was calculated by dividing the number of calories from UPFs by the total number of calories consumed by an individual. The data were averaged across the two days. For this analysis, individuals were included in the sample if they completed two 24-hour dietary recalls which were “reliable and

met the minimum criteria" according to NHANES documentation. [95] The analysis was also restricted to individuals who reported consuming 500 – 5000 kilocalories; previous studies using NHANES data have used this range to restrict to plausible data. [89]

3.3.5 Covariates

The covariates of interest were adolescent age (in years), sex (male/female), race/ethnicity, sedentary time, vigorous recreational activity, moderate recreational activity; household income-to-poverty ratio, household respondent marital status, and household respondent education level. Race/ethnicity categories were Non-Hispanic White, Non-Hispanic Black, Mexican American, Other Hispanic ethnicity, and other race. Sedentary time was split into low sedentary time (6 hours or less) or high sedentary time (greater than 6 hours). Vigorous recreational activity and moderate recreational activity were recoded into binary yes/no variables. Household income-to-poverty ratio was determined by NHANES through dividing household income by the federal poverty guidelines. [95] The household respondent is an adult member of the household who responded to some aspects of the survey on behalf of the household. Household respondent marital status was recoded as "married/partnered" or "not married/partnered." Similarly, household respondent education level was recoded as "high school graduate" and "not high school graduate." [95]

3.3.6 Statistical Analysis

For descriptive statistics, weighted means and proportions were calculated. Simple linear regressions were used to assess differences in continuous variables and Rao-Scott Chi-square tests were used for categorical variables. For the main analyses, multivariable linear regressions were used to assess the associations between household food insecurity and SNAP participation

with UPF intake. For both sets of analyses, Model 1 adjusted for age, sex, and TEI. For the food insecurity analyses, Model 2 adjusted for all covariates and TEI. For the SNAP analyses, Model 2 adjusted for all covariates, TEI, and household food security status. All analyses used survey procedures that accounted for the survey strata, clustering, and weights. All original 2-year dietary survey weights were recalculated to match the 10-year study period. The analyses were conducted in SAS Version 9.4 (SAS Institute, Cary, NC).

3.3.7 Results

In this sample, 15.9% of lower-income U.S. adolescents experienced marginal food security and 33.8% experienced food insecurity. Adolescents with food insecurity were more likely to be non-Hispanic Black, Mexican American, other Hispanic ethnicity, or other race ($p < .0001$). Food security status was also associated with vigorous recreational activity ($p = 0.03$). Adolescents with food insecurity were more likely to come from households that were lower-income ($p < .0001$), participating in SNAP ($p < .0001$), and where the household respondent was not married/partnered ($p = 0.002$) and not a high school graduate ($p = 0.0002$) (Table 7).

In multivariable analyses, household food insecurity was not associated with adolescent UPF intake. In Model 1, the p-value for food insecurity was 0.50 and in Model 2, the p-value was 0.83 (Table 8). However, household SNAP participation was associated with higher UPF intake. In Model 1, SNAP participation was associated with 2.5% higher UPF intake ($p = 0.04$). In Model 2, SNAP participation was associated with 2.7% higher UPF intake ($p = 0.04$) after controlling for all covariates, TEI, and household food security status (Table 9). The interaction term between household food insecurity and household SNAP participation was not statistically significant.

3.3.8 Discussion

In this national sample of lower-income U.S. adolescents aged 12 – 19 years, SNAP participation was associated with higher UPF intake; however, the association between food insecurity and UPF intake was not statistically significant. Additionally, the adjusted mean intakes for all lower-income adolescent groups were high, ranging from 63.2% to 65.9%. From a public health standpoint, the association between household SNAP participation and high UPF intake in lower-income adolescents has important policy implications. Additionally, the high levels of UPF intake in all lower-income adolescents, regardless of food security and/or SNAP status, is a major public health concern.

The lack of association between food insecurity and UPF intake differs from a few related findings. For example, the same analysis in lower-income adults found an association between food insecurity and UPF intake. [62] However, this difference might be because food-secure adults had UPF intakes lower [62] than the national average [86] while both food-secure and food-insecure adolescents had high UPF intakes. Similarly, Chiong et al. have found higher UPF intake in U.S. adolescents at risk for food insecurity when examining food insecurity as an effect modifier of UPF intake. [98] However, their analysis was descriptive and did not control for potential confounders. Finally, while our finding is different from some researchers who have found an association between food insecurity and poor dietary intake in U.S. children and/or adolescents, [99, 100] it aligns with Rossen et al. who found little evidence of an association. [31]

Meanwhile, the finding for the association between household SNAP participation and higher UPF intake in U.S. adolescents corresponds with several prior studies. [59, 61, 93] [101] Firstly, the study in lower-income U.S. adults found a similar association. [62] In children and/or adolescents, researchers found that SNAP participation was associated with higher SSB intake,

[101] worse diet quality [61], [93] and higher intake of processed meat. [59] However, Chen et al. found no association between the combination of SNAP and school meal participation with dietary quality in low-income U.S. children. [102] Although the associations between food insecurity, SNAP participation and UPF intake in adolescents need further exploration, all lower-income adolescents could benefit from reduced UPF intake.

The health repercussions of high UPF intake is troubling. Compared to less processed foods, UPFs produce lower satiety [15] and have been associated with binge-eating. [77] They have also been shown to be potentially addictive neurologically and behaviorally. [103] This is a particularly negative exposure for the adolescent brain [104] which is still developing and for individuals experiencing stress. [10] Accordingly, for adolescents experiencing food insecurity, which itself is a stressor, [105] the negative consequences of high UPF intake could be especially harmful. In other words, while UPF intake may be similar for all lower-income adolescents, the addictive potential (and subsequent risk of higher intake) could be worse for adolescents experiencing food insecurity. Finally, as dietary preferences and habits are formed through childhood and adolescence, excessive consumption of UPFs could create poor future dietary habits. Therefore, despite no significant association between food insecurity and UPF intake in the present study, the trend of high UPF intake in all lower-income adolescents is worrying and might be particularly damaging for adolescents at risk of experiencing food insecurity.

It is also concerning that adolescents that come from households that participate in SNAP are more likely to consume UPFs. Research has shown that even with SNAP benefits, most participants struggle to follow a healthy diet due to cost and lack of cooking time. [106] While SNAP participation has been shown to improve food insecurity, [107] it might facilitate UPF purchases for cost and convenience. [106] Thus, it is possible that some households might

improve their food security status through SNAP participation but this change may also increase their UPF intake due to the barriers of money and time. While this analysis was cross-sectional and cannot determine if initiation of SNAP participation improved food security and increased UPF intake, longitudinal analyses could examine this question.

Likewise, future research should corroborate these associations as well as examine potential public health interventions that can improve UPF intake in all lower-income U.S. adolescents and adolescents from SNAP-participating households. For example, similar research that examines the association between adolescent self-reported food insecurity and UPF intake might be helpful. Longitudinal analyses that examine the association of food insecurity and SNAP participation with UPF intake from adolescence to adulthood could inform how UPF intake changes with age and when to intervene to improve UPF intake in certain sub-populations. Qualitative work that examines the behavioral, neighborhood, and social influences on the association between household SNAP participation and higher adolescent UPF intake could be helpful to assess points of intervention. Finally, as main drivers of this association are clearly identified, pertinent public health interventions could be empirically tested and implemented.

For instance, several existing policies and programs possibly could improve the association between household SNAP participation and adolescent UPF intake. Research has shown that a fruit/vegetable incentive program improved purchasing of those foods. [108] The Healthy Incentives Pilot (HIP) [109] and Double-up Food Bucks [110] have been shown to improve dietary intake in SNAP participants. Access to a new neighborhood supermarket has also been shown to improve SNAP participant dietary quality. [111] Research has shown that when children that participate in SNAP acquire food for free in a school setting, the nutritional quality of those foods tends to be higher [112] so school-based free food acquisitions could be

encouraged and expanded. Finally, even with SNAP benefits, cost [106] has been cited as a barrier to following a healthy diet for SNAP participants so perhaps higher SNAP benefits could ameliorate this association. Therefore, numerous potential options could improve UPF intake in lower-income adolescents from SNAP-participating households.

This paper has several strengths. To begin, it is the first to conduct a rigorous quantitative analysis of the association between household food insecurity and SNAP status with UPF intake in lower-income U.S. adolescents – an important public health topic that has not been previously studied. Secondly, the findings are broadly applicable due to the usage of recent national data. This paper also has a few limitations. This analysis used cross-sectional data so causal inference cannot be drawn. Additionally, 24-hour dietary recalls are prone to recall bias. [113] Finally, the exposures of household food insecurity and household SNAP participation might be experienced differently by adolescents compared to other household members. Nevertheless, this paper contributes a novel perspective to the current literature on food insecurity, SNAP participation, and adolescent dietary intake.

In summary, household SNAP participation – but not household food insecurity – was associated with higher UPF intake in a national sample of lower-income U.S. adolescents aged 12 – 19 years. Despite this association, UPF intake was high for all lower-income adolescents. Policies and programs that reduce UPF intake for all lower-income U.S. adolescents would be highly beneficial. While SNAP has been shown to improve food security,[114] it is important to consider how it might impact nutrition security. [115] It is worrying that adolescents from households participating in the program report high consumption of foods that are potentially addictive [103] and known to increase chronic disease risk. [84] [65] Further research into this

topic and greater investment in effective public health interventions and policies to promote healthful eating habits among lower-income adolescents are warranted.

3.4 Tables

Table 7: Associations between household food insecurity and sociodemographic and health characteristics in a lower-income sample of adolescents aged 12 - 19 years in NHANES cycles 2007 - 2016

Adolescent Characteristics	Full sample weighted % or mean	N or weighted SE	Full food security weighted % or mean	N or weighted SE	Marginal food security weighted % or mean	N or weighted SE	Food insecurity weighted % or mean	N or weighted SE	*P-value*
Overall (%)	100	3067	50.3	1409	15.9	527	33.8	1131	
Female (%)	52.1	1557	52.6	711	57.2	293	49.1	553	0.17
Race/ethnicity (%)									**<.0001**
Non-Hispanic White	46.2	706	54.3	367	42.1	109	36.1	230	
Non-Hispanic Black	17.9	814	15.2	347	21.4	156	20.3	311	
Mexican American	20.2	853	15.7	355	20.5	136	26.7	362	
Other Hispanic ethnicity	8.6	391	7.5	171	10.3	76	9.4	144	
Other race/ethnicity	7.1	303	7.2	169	5.8	50	7.5	84	
Vigorous recreational activity in typical week (%)	57.7	1716	60.7	823	50.4	275	56.6	618	**0.03**
Moderate recreational activity in typical week (%)	52.4	1482	55.2	701	50.6	259	49.2	522	0.16
Low Sedentary Activity (%)	31.2	915	30.7	407	34.2	171	30.4	337	0.62
Age (years), mean (SE)	15.4	0.06	15.4	0.09	15.6	0.16	15.3	0.1	0.17
Household Characteristics									
HH Respondent Education ≥ High school graduate (%)	70.3	1967	76	967	68.1	335	62.9	665	**0.0002**
HH Respondent Married/Partnered (%)	62.8	1865	68.3	925	57.3	309	57	631	**0.002**
HH Income to Poverty Ratio, mean (SE)	1.42	0.03	1.67	0.04	1.32	0.07	1.09	0.04	**<.0001**
SNAP Participation (%)	36.5	1238	23.8	393	40.3	240	53.5	605	**<.0001**

* Statistically significant estimates at alpha = 0.05 are bolded.
Analyses were conducted using survey procedures that take into account the complex survey design.
Rao-Scott Chi-squared tests were used for categorical variables and linear regressions were used for continuous variables.
According to the United States Department of Agriculture (USDA), full food security is defined as "no reported indications of food-access problems or limitations," marginal food security is defined as "one or two reported indications—typically of anxiety over food sufficiency or shortage of food in the house. Little or no indication of changes in diets or food intake," and food insecurity is defined as "a household-level economic and social condition of limited or uncertain access to adequate food." Definitions are from the USDA Economic Research Service (ERS): https://www.ers.usda.gov/topics/food-nutrition-assistance/food-security-in-the-us/definitions-of-food-security.aspx
Abbreviations: HH = Household; NHANES = National Health and Nutrition Examination Survey; SE = Standard Error; SNAP = Supplemental Nutrition Assistance Program

Table 8: Linear regressions between food insecurity and ultra-processed food intake (as percentage of total energy) in lower-income (300% FPL and below) adolescents aged 12 - 19 years (n = 3067) in NHANES cycles 2007 - 2016

	Model 1					Model 2				
	Adjusted Mean	Estimate	95% CI LL	95% CI UL	P-value	Adjusted Mean	Estimate	95% CI LL	95% CI UL	P-value
Full food security	66.3	Ref.				64.4	Ref.			
Marginal food security	66.5	0.1	-2.7	3.0	0.92	64.5	0.2	-2.9	3.2	0.92
Food insecurity	65.7	-0.7	-2.7	1.3	0.50	64.1	-0.2	-2.4	1.9	0.83
P-for-trend					0.53					0.84

* Statistically significant estimates at alpha = 0.05 are bolded.
Analyses were conducted using survey procedures that take into account the complex survey design.
Model 1 is adjusted for total energy intake, age, and sex. Model 2 is adjusted for total energy intake, adolescent age, sex, race/ethnicity, vigorous recreational activity, moderate recreational activity, sedentary time; household respondent education, marital status, and income (linear and quadratic term).
According to the United States Department of Agriculture (USDA), full food security is defined as "no reported indications of food-access problems or limitations," marginal food security is defined as "one or two reported indications—typically of anxiety over food sufficiency or shortage of food in the house. Little or no indication of changes in diets or food intake," and food insecurity is defined as "a household-level economic and social condition of limited or uncertain access to adequate food." Definitions are from the USDA Economic Research Service (ERS): https://www.ers.usda.gov/topics/food-nutrition-assistance/food-security-in-the-us/definitions-of-food-security.aspx
Abbreviations: CI = Confidence interval; FPL = federal poverty line; LL = lower limit; NHANES = National Health and Nutrition Examination Survey; UL = upper limit

Table 9: Linear regressions between household SNAP participation and ultra-processed food intake (as percentage of total energy) in lower-income (300% FPL and below) adolescents aged 12 - 19 years (n = 3067) in NHANES cycles 2007 - 2016

	Model 1					Model 2				
	Adjusted Mean	Estimate	95% CI LL	95% CI UL	P-value	Adjusted Mean	Estimate	95% CI LL	95% CI UL	P-value
SNAP non-participation	65.2	Ref.				63.2	Ref.			
SNAP participation	67.7	2.5	0.2	4.8	**0.04**	65.9	2.7	0.1	5.2	**0.04**

* Statistically significant estimates at alpha = 0.05 are bolded.
Analyses were conducted using survey procedures that take into account the complex survey design.
Model 1 is adjusted for total energy intake, age, and sex. Model 2 is adjusted for total energy intake, adolescent age, sex, race/ethnicity, vigorous recreational activity, moderate recreational activity, sedentary time; household respondent education, marital status, income (linear and quadratic term), and household food security status.
According to the United States Department of Agriculture (USDA), full food security is defined as "no reported indications of food-access problems or limitations," marginal food security is defined as "one or two reported indications—typically of anxiety over food sufficiency or shortage of food in the house. Little or no indication of changes in diets or food intake," and food insecurity is defined as "a household-level economic and social condition of limited or uncertain access to adequate food." Definitions are from the USDA Economic Research Service (ERS): https://www.ers.usda.gov/topics/food-nutrition-assistance/food-security-in-the-us/definitions-of-food-security.aspx
Abbreviations: CI = Confidence interval; FPL = federal poverty line; LL = lower limit; NHANES = National Health and Nutrition Examination Survey; UL = upper limit

Chapter 4 Aim 3: Associations between Food Insecurity and Diabetes Risk Factors in Adolescents Aged 12 - 19 Years in the National Health and Nutrition Examination Survey (NHANES) 2007 - 2016

4.1 Abstract

Background: Food insecurity has been associated with diabetes risk factors in low-income U.S. adults; however, limited research has investigated these associations in lower-income adolescents.

Objective: Evaluate the association between food insecurity and diabetes risk factors in a national sample of lower-income U.S. adolescents.

Subjects: 3412 lower-income (300% federal poverty line and below) U.S. adolescents aged 12-19 years from the National Health and Nutrition Examination Survey (NHANES) cycles 2007-2016.

Methods: Household food security status was measured using the 18-item Food Security Survey Module. Simple and multivariable linear and logistic regressions were used to assess the association between food security status and fasting plasma glucose (FPG), oral glucose tolerance (OGTT), Hemoglobin A1C (HbA1C), homeostatic model assessment – insulin resistance (HOMA-IR), and triglyceride-to-high density lipoprotein cholesterol ratio (TG/HDL-c). The analyses were adjusted for household and adolescent demographic and health characteristics.

Results: The weighted prevalence of marginal food security was 15.4% and of food insecurity was 32.9%. After multivariate adjustment, food insecurity was associated with a 0.04% higher

HbA1C (95% CI: 0.00, 0.09, p-value = 0.04). The overall trend between food security status and HbA1C was also statistically significant (p-for-trend = 0.045). There were no significant associations between household food security and adolescents' FPG, OGTT, HOMA-IR, and TG/HDL-c ratio.

Conclusions: Food insecurity was associated with higher HbA1c in a national sample of lower-income U.S. adolescents aged 12-19 years, suggesting an association between food insecurity and diabetes risk in lower-income U.S. adolescents. This topic warrants further investigation.

Abbreviations:

FPG: fasting plasma glucose

HbA1C: Hemoglobin A1C

HOMA-IR: homeostatic model assessment – insulin resistance

NHANES: National Health and Nutrition Examination Survey

OGTT: oral glucose tolerance

TG/HDL-c: triglyceride-to-high density lipoprotein cholesterol ratio

4.2 Introduction

In the United States (U.S.), approximately one in 12 individuals is affected by type 2 diabetes, [21] a chronic disease characterized by insulin resistance and high blood glucose levels. [116] In the long term, type 2 diabetes can cause complications such as retinopathy, neuropathy, kidney damage, [117] and premature death. [118] In 2017, the U.S. spent approximately $327 billion on healthcare costs related to diabetes [119] and future costs may increase. [120] In particular, the increasing incidence of type 2 diabetes in adolescents [121] is a concerning trend. Approximately 1 in 5 U.S. adolescents (aged 12 to 18 years) are affected by prediabetes [22] and the age of onset for type 2 diabetes has become lower over time. [122] Earlier age of onset has

been associated with more rapid and severe disease progression [123] including earlier complications [124] and a reduction in life expectancy. [125] Thus, due to the prevalence and severity of this disease, type 2 diabetes in U.S. adolescents is a critical public health issue.

Food insecurity, an important social determinant of health, has been associated with diabetes risk factors in U.S. adults. [36] Food insecurity is defined by the United States Department of Agriculture (USDA) as a "household-level economic and social condition of limited or uncertain access to adequate food" [11] and affects approximately 1 in 10 U.S. households. [12] In U.S. adults, food insecurity is associated with poor dietary quality [30] which is a known risk factor for type 2 diabetes. [116] Seligman et al. has found that food insecurity was associated with 2.1 higher odds of diabetes in lower-income U.S. adults. [36] In younger adults (ages 20 to 39), Lee et al. found that food insecurity was associated with a 1.36 higher odds of prediabetes or type 2 diabetes. [40]

Food insecurity is more prevalent among households with children, affecting 1 in 8 of such households [1]. However, the current evidence base for the association between food insecurity and diabetes risk in children/adolescents is limited. Presently, one research study using data from Minnesota students found that food insecurity was associated with higher prediabetes risk for Non-Hispanic White, Hispanic/Latinx, and Non-Hispanic Black youth; however, this information cannot be extrapolated to the national level. [126] Additionally, Lee et al. has found that food insecurity is associated with 1.94 higher prediabetes risk (as measured by hemoglobin A1C) in a national sample of U.S. adolescents; however, this study did not examine additional important risk factors such as oral glucose tolerance or homeostatic model assessment – insulin resistance. [43] Thus, this sparse evidence should be confirmed with data that uses additional measures of diabetes risk factors at the national level.

The purpose of this study is to investigate the association between household food insecurity and type 2 diabetes risk factors in a sample of lower-income (300% federal poverty line or below) U.S. adolescents aged 12 - 19 years using data from the National Health and Nutrition Examination Survey (NHANES) cycles 2007 - 2016. This study would be among the first to comprehensively examine multiple diabetes risk factors (including oral glucose tolerance, homeostatic model assessment – insulin resistance, and triglyceride to high-density lipoprotein cholesterol ratio) by adolescents' household food security status using a large, recent, and national sample. It is hypothesized that food insecurity will be associated with higher levels of all type 2 diabetes risk factors.

4.3 Methods

4.3.1 Data Source

NHANES is a cross-sectional survey which collects health and nutrition data on the non-institutionalized U.S. population. It utilizes a complex design (using strata, clusters, and weights). From 1999 onwards, demographics, dietary, examination, laboratory, and questionnaire data have been collected continuously. [127]

4.3.2 Participants

The participants in the sample are 3412 lower-income (300% federal poverty line and below) U.S. adolescents aged 12 - 19 years from NHANES cycles 2007 - 2016. We limited to 300% federal poverty line and below to limit confounding by income as done in previous studies. [36] [89] Similar to a previous study, [128] we pooled data from cycles 2007 - 2008, 2009 - 2010, 2011 - 2012, 2013 - 2014, and 2015 - 2016 to ensure an appropriate sample based on size and time trends. Participants were included if they had full information on the exposure, covariates,

and at least one diabetes risk factor. For outcome variables that required fasting, individuals were included in the sample if they reported fasting for 9 - 24 hours.

4.3.3 Exposure

The exposure variable is household food insecurity, measured by the USDA Household Food Security Survey Module [69] – a broadly used and previously validated instrument. [50] This module includes 18 questions about the food security status of a household with children and is completed by an adult member of the household. [127] A score of 0 - 18 is created from the sum of all affirmative responses, with a higher score denoting greater food insecurity. Zero affirmative responses indicates full food security, 1 - 2 indicates marginal food security, 3 - 7 indicates low food security, and 8+ indicates very low food security. For this analysis, we grouped "low food security" and "very low food security" into the broader category of "food insecurity" as USDA guidelines permit. [69]

4.3.4 Outcomes

The outcomes of interest are: fasting plasma glucose (FPG), hemoglobin A1C (HbA1C), oral glucose tolerance (OGTT), homeostatic model assessment – insulin resistance (HOMA-IR), and triglyceride to high-density lipoprotein cholesterol ratio (TG/HDL-c). For NHANES participants, all of these measures and/or their individual components are obtained at the mobile examination center (MEC) via blood samples. [127] FPG, HbA1C, and OGTT are directly measured in NHANES. [127] FPG values indicate current fasting plasma glucose levels. HbA1C is a non-fasting measure of the percentage of glycosylated hemoglobin in the blood and represents average plasma glucose levels over the past three months. [129] OGTT is a measure of glucose tolerance that compares a baseline FPG measurement to plasma glucose levels two hours after

the consumption of 75 grams of pure glucose. [130] Meanwhile, HOMA-IR and TG/HDL-c are derived from other measures [127] taken in the NHANES MEC. HOMA-IR is a measure of insulin resistance that is calculated from FPG and fasting insulin using the following formula: *((fasting plasma glucose in mg/dL)*(fasting insulin in uU/mL))/405.* [131] TG/HDL-c is a novel measure of diabetes risk that is calculated by dividing fasting triglyceride values by non-fasting HDL-c values. [132]

Binary versions of the outcome variables were constructed based on established cutoffs associated with higher diabetes risk. [133] For FPG, values less than 100 mg/dL were classified as normal FPG and values of 100 mg/dL or higher were classified as high FPG. For HbA1C, values below 5.7% were classified into normal HbA1C and values at 5.7% or higher were classified as high HbA1C. For OGTT, values below 140 mg/dL were classified as normal OGTT and values 140 mg/dL or higher were classified as high OGTT. Because no clinical cutoffs for HOMA-IR and TG/HDL-c exist for U.S. adolescents, values were considered high if they were above the 75th percentile, a categorization previously used by Lee et al. [134]

4.3.5 Covariates

Covariates included age (in years), sex (male/female), race/ethnicity, sedentary activity, vigorous recreational activity, moderate recreational activity, household income-to-poverty ratio, household respondent education level, and household respondent marital status. Briefly, race/ethnicity was recoded to the following categories: non-Hispanic White, non-Hispanic Black, Mexican American, Other Hispanic ethnicity, and other race/ethnicity. Sedentary activity was recoded to a binary variable such that someone who engaged in more than 360 minutes of sedentary activity per day was considered to engage in “high sedentary activity” and someone who engaged in 360 minutes or less of sedentary activity per day was considered to engage in

"low sedentary activity." Vigorous and moderate recreational activity were recoded to binary yes/no variables. [135] Household income-to-poverty ratio is a variable provided by NHANES which is calculated by dividing household income by the federal poverty line from the Department of Health and Human Services. [127] Household respondent education level was recoded into "≥ high school graduate" or "< high school graduate." Household respondent marital status was recoded to a binary yes/no variable in which "married/partnered" was coded as "yes" and "single/divorced/widowed" was coded as "no."

4.3.6 Statistical analysis

For descriptive statistics, weighted means and percentages were calculated. Simple linear regressions were used to assess differences in continuous variables by food security status and Rao-Scott chi-squared tests were used to assess differences in categorical variables by food security status. To examine the associations between household food security and diabetes risk factors, we used multivariable linear regression for continuous diabetes risk factors and multivariable logistic regression for clinical cut-points, adjusting for all study covariates. Complex survey weights were recalculated to reflect the probability of being sampled in the 10-year study period. Survey weights were applied to all analyses specific to the end-point of interest, e.g. MEC weights for HbA1C, fasting weights for FPG, HOMA-IR, and TG/HDL-c, and OGTT weights for OGTT. All analyses used survey procedures in SAS 9.4 (SAS Institute, Cary, NC) that accounted for the complex survey design strata, clustering, and weights.

4.4 Results

The analytical samples for the diabetes risk factors are: 3412 for HbA1C, 1488 for TG/HDL-c, 1507 for FPG, 1457 for HOMA-IR, and 1323 for OGTT. In the sample, the weighted prevalence

of marginal food security was 15.4% and the weighted prevalence of food insecurity was 32.9%. Adolescents with food insecurity were more likely to be non-Hispanic Black, Mexican American, or Other Hispanic ethnicity ($p < 0.0001$) and less likely to engage in moderate recreational activity ($p = 0.03$) (Table 10). Adolescents with food insecurity were also more likely to have a household respondent with lower educational attainment ($p < 0.0001$), who was not married/partnered ($p < 0.0001$), and with lower income ($p < 0.0001$) (Table 10).

In examining the multivariate-adjusted associations between household food security and continuous diabetes risk factors, food insecurity was associated with 0.04% (95% CI: 0.00%, 0.09%, p=0.04) higher HbA1C compared to full food security (Table 11). There was a significant trend between food insecurity and higher HbA1C (p-trend = 0.045) (Table 11). The associations between household food security and continuous FPG, OGTT, HOMA-IR, and TG/HDL-c were not significant. In examining the associations between household food security and binary diabetes risk factors, the p-for-trend for HbA1C was statistically significant at $p = 0.01$ but the association was attenuated in the multivariable-adjusted model such that it was no longer statistically significant (Table 12). Similar to Table 11, the associations between household food security and clinical cut-points for FPG, OGTT, HOMA-IR, and TG/HDL-c were not significant (Table 12).

4.5 Discussion

In this study, food insecurity was significantly associated with slightly higher continuous HbA1C after adjustment for household and adolescent characteristics, which suggests a possible association between food insecurity and diabetes risk in lower-income U.S. adolescents. Overall, this study fortifies the evidence base by confirming the findings of two previous studies [126]

[43] by using data from a large, recent, national sample and adding information on risk factors such as HOMA-IR, OGTT, and TG/HDL-c.

The findings of this study agree with the two previous publications on this topic that found an association between food insecurity and prediabetes in a national sample of U.S. adolescents using HbA1C [43] and another study that found that food insecurity was associated with higher prediabetes risk in adolescents residing in Minnesota, US. [126] Furthermore, this study aligns with the research of Malik et al. who found that U.S. individuals aged 10 - 35 years with type 2 diabetes were more likely to come from households experiencing food insecurity. [136] On the other hand, Marjerrison et al. found that there was an initial association between food insecurity and higher HbA1C in Canadian youth that attenuated after multivariable adjustment. [137] However, it is important to note that Canadian societal factors might differ from those in the U.S. and thus, this finding may not apply to U.S. populations.

It is important to consider factors that might be driving the association between food insecurity and higher HbA1C in lower-income U.S. adolescents. Food insecurity has been associated with poorer dietary quality [30] and diabetes risk [36] in U.S. adults. In U.S. children, Landry et al. [138] and Fram et al. [139] found that food insecurity was associated with higher intake of sugars. However, a systematic review by Hanson and Connor suggests that the association between food insecurity and poor dietary quality is mixed. [30] It is possible that specific components of diet related to diabetes risk (such as refined carbohydrates or sugars [140]) are being overconsumed in populations with food insecurity or that there is a true difference between the food intake of food-secure and food-insecure adolescents that is difficult to detect with current dietary assessment instruments. Thus, it is possible that dietary factors may play a role in this association.

Food insecurity has been associated with loss-of-control eating in adolescents [141] and binge-eating in children with obesity. [142] It is possible, therefore, that eating behavior differences could potentially explain the association between food insecurity and higher HbA1C. It has been proven that both voluntary and involuntary food restriction can cause changes in eating behavior. [143] Binge and loss-of-control eating patterns have been linked to higher insulin resistance, in response to higher calorie/fat intake, [144] and higher type 2 diabetes risk. [145, 146] It is possible that if youth with food insecurity are more likely to consume excessively large portions when food is available, this pattern could impact type 2 diabetes risk factors. Given the irregularity of such patterns, HbA1C might be more likely to capture the long-term impact of such behavior compared to one-time fasting measures. Further investigation of adolescent eating behavior in response to food insecurity might elucidate potential mechanisms for future diabetes risk.

Although food insecurity was associated with HbA1C in this study, there were no associations found between food insecurity and FPG, HOMA-IR, OGTT, and TG/HDL-c levels. It is possible that an association was found between food insecurity and HbA1C because HbA1C is more robust to day-to-day fluctuation [147] and certain types of error/bias. Conversely, FPG, HOMA-IR, OGTT, and TG/HDL-c include measures of plasma glucose, insulin, and/or lipids at one moment in time [127] that can be susceptible to fluctuation due to circadian rhythm. [148] [149] Furthermore, FPG, HOMA-IR, OGTT, and TG/HDL-c all require fasting and thus can be impacted by error/bias such as recall bias or social desirability bias [83] that can affect reporting of fasting information. For example, incorrect information on fasting time or status could greatly impact FPG interpretation but would have no effect on HbA1C. Thus, it is possible that an

association between food insecurity and HbA1C is noticeable because HbA1C is a measure that is more resistant to external influence in this specific instance; however, the differential results between HbA1C and the other biomarkers still merits further investigation.

This study has a several strengths worth highlighting. To begin, this study is one of the first to comprehensively assess the association between food insecurity and numerous diabetes risk factors including OGTT, HOMA-IR, and TG/HDL-c in a large, recent, nationally representative sample of lower-income U.S. adolescents (including an oversample of non-Hispanic Black and Hispanic populations). We acknowledge limitations, including the cross-sectional design which precludes causation. Social desirability bias might exist for sensitive variables such as food insecurity and income while recall bias and social desirability bias may exist for fasting status and time reporting. [83] While it is impossible to completely correct for such biases, NHANES has strict protocols including interviewer training and data cleaning to maximize the collection of highly accurate data. [127] Finally, household food insecurity might not necessarily be representative of the food insecurity experience of an individual adolescent in that household. That being said, there is currently no measure of individual child food security in NHANES and the household food insecurity measure has been previously validated. [50] While this study has some limitations, it provides a rigorous and comprehensive overview of the association between household food insecurity and diabetes risk factors in lower-income U.S. adolescents.

The public health implications of a potential association between food insecurity and higher HbA1C and/or diabetes risk in U.S. adolescents are important. It is possible that food insecurity could play a small role in the rising incidence of type 2 diabetes [121] in this age group, a trend associated with higher disease burden [123] and likely higher healthcare costs.

Although the mechanism for the association between food insecurity and higher HbA1C in this age group is unclear, interventions that improve food security could ameliorate this trend as well as provide numerous other health benefits. For example, healthy incentive programs such as Double-Up Food Bucks (associated with the Supplemental Nutrition Assistance Program) could improve both food security and dietary quality [150] which could help reduce type 2 diabetes risk. The spillover effects of such programs would likely also benefit other aspects of mental and physical health [90] for this age group.

In summary, household food insecurity was associated with slightly higher HbA1C levels in a national sample of lower-income U.S. adolescents aged 12 - 19 years. Household food insecurity was not associated with short-term glucose levels, insulin resistance, oral glucose tolerance, or triglyceride-to-HDL-cholesterol ratio. Thus, there is some evidence to suggest an association between food insecurity and diabetes risk in lower-income U.S. adolescents which has been corroborated by a few other studies. [126] [43] Regardless, additional research that can further confirm these findings and establish a causal mechanism for this association – such as investigating the role of dietary quality and/or eating behavior in this association – is warranted. Currently, the overall U.S. adolescent population has been shown to consume a poor diet [151] and is experiencing a surge in type 2 diabetes incidence. [121] Thus, all U.S. adolescents could benefit from policies and programs that improve dietary quality and type 2 diabetes risk. Furthermore, by this rationale, policies and programs that increase access to nutritious foods could disproportionately benefit U.S. adolescents with food insecurity in terms of their dietary intake, diabetes risk, and overall health. [90]

4.6 Tables

Table 10: Associations between household food insecurity and sociodemographic variables in a lower-income (300% federal poverty line and below) sample of adolescents aged 12 - 19 years in NHANES cycles 2007 - 2016

Adolescent Characteristics	Overall weighted % or mean	N or weighted SE (n = 3412)	Full food security weighted % or mean	N or weighted SE (n = 1550)	Marginal food security weighted % or mean	N or weighted SE (n = 585)	Food insecurity weighted % or mean	N or weighted SE (n = 1277)	*P-value*
Female (%)	50.3	1678	51	762	52.6	311	48.1	605	0.33
Race/ethnicity (%)									**<.0001**
Non-Hispanic White	46.4	797	54.3	419	39.7	113	37.3	265	
Non-Hispanic Black	17.0	876	14	366	21.5	173	19.7	337	
Mexican American	19.6	952	16	391	21	156	24.6	405	
Other Hispanic ethnicity	9.3	456	7.8	197	11.4	89	10.6	170	
Other race/ethnicity	7.6	331	7.9	177	6.5	54	7.7	100	
Vigorous recreational activity in typical week (%)	57.4	1950	59.2	916	52.1	307	57	727	0.11
Moderate recreational activity in typical week (%)	52.5	1652	55.6	773	49.3	277	49.3	602	**0.03**
Low Sedentary Activity (%)	28.5	1028	27.7	452	29.5	185	29.4	391	0.69
Age (years), mean (SE)	15.3	0.05	15.3	0.07	15.4	0.1	15.2	0.08	0.39
Household Characteristics									
HH Respondent Education ≥ High school graduate (%)	69.8	2195	74.7	1066	67.1	369	63.3	760	**<.0001**
HH Respondent Married/Partnered (%)	62.9	2061	69.2	1005	57.6	336	55.4	720	**<.0001**
HH Income to Poverty Ratio, mean (SE)	1.43	0.03	1.67	0.03	1.23	0.05	1.15	0.04	**<.0001**

* Statistically significant estimates at alpha = 0.05 are bolded.
All analyses were conducted using survey procedures that account for the complex survey design including the strata, clusters, and weights.
Rao-Scott Chi-squared tests were used for categorical variables and simple linear regressions were used for continuous variables.
According to the United States Department of Agriculture (USDA), full food security is defined as "no reported indications of food-access problems or limitations." Marginal food security is defined as "one or two reported indications—typically of anxiety over food sufficiency or shortage of food in the house. Little or no indication of changes in diets or food intake." Food insecurity is defined as "a household-level economic and social condition of limited or uncertain access to adequate food." These definitions are from the USDA Economic Research Service (ERS): https://www.ers.usda.gov/topics/food-nutrition-assistance/food-security-in-the-us/definitions-of-food-security.aspx
Abbreviations: HH = Household; NHANES = National Health and Nutrition Examination Survey; SE = Standard Error

Table 11: Linear regressions between food insecurity and diabetes risk factors in a lower-income (300% federal poverty line and below) sample of adolescents aged 12 - 19 years (n = 3412) in NHANES cycles 2007 - 2016

		Model 1				Model 2			
	N	Estimate	95% CI LL	95% CI UL	P-value	Estimate	95% CI LL	95% CI UL	P-value
HbA1C	3412								
Full food security		Ref.				Ref.			
Marginal food security		0.02	-0.05	0.08	0.65	0.00	-0.07	0.07	0.99
Food insecurity		0.06	0.02	0.10	**0.007**	0.04	0.00	0.09	**0.041**
P-for-trend					**0.007**				**0.045**
TG/HDL Ratio	1488								
Full food security		Ref.				Ref.			
Marginal food security		-0.08	-0.29	0.12	0.42	-0.11	-0.31	0.09	0.28
Food insecurity		0.03	-0.16	0.22	0.75	0.00	-0.18	0.19	0.99
P-for-trend					0.82				0.95
Fasting Plasma Glucose (mg/dL)	1507								
Full food security		Ref.				Ref.			
Marginal food security		0.31	-2.56	3.17	0.83	0.16	-2.68	3.00	0.91
Food insecurity		0.33	-1.11	1.77	0.65	0.27	-1.11	1.65	0.70
P-for-trend					0.64				0.69
HOMA-IR	1457								
Full food security		Ref.				Ref.			
Marginal food security		0.08	-0.35	0.52	0.70	-0.13	-0.56	0.29	0.53
Food insecurity		0.23	-0.13	0.60	0.21	0.00	-0.40	0.40	0.99
P-for-trend					0.22				0.97
OGTT (mg/dL)	1323								
Full food security		Ref.				Ref.			
Marginal food security		-1.04	-5.68	3.60	0.66	-1.66	-6.38	3.06	0.49
Food insecurity		2.87	-1.10	6.83	0.15	3.10	-1.15	7.35	0.15
P-for-trend					0.19				0.18

* Statistically significant estimates at alpha = 0.05 are bolded.
All analyses were conducted using survey procedures that account for the complex survey design including the strata, clusters, and weights.
Model 1 is age- and sex-adjusted. Model 2 is adjusted for adolescent age, sex, race/ethnicity, vigorous recreational activity, moderate recreational activity, sedentary time; household respondent education, marital status, and income (linear and quadratic term).
According to the United States Department of Agriculture (USDA), full food security is defined as "no reported indications of food-access problems or limitations." Marginal food security is defined as "one or two reported indications—typically of anxiety over food sufficiency or shortage of food in the house. Little or no indication of changes in diets or food intake." Food insecurity is defined as "a household-level economic and social condition of limited or uncertain access to adequate food." These definitions are from the USDA Economic Research Service (ERS): https://www.ers.usda.gov/topics/food-nutrition-assistance/food-security-in-the-us/definitions-of-food-security.aspx
Abbreviations: CI = Confidence interval; HDL = high density lipoprotein; HOMA-IR = homeostatic model assessment - insulin resistance; LL = lower limit; mg/dL = milligram/deciliter; NHANES = National Health and Nutrition Examination Survey; OGTT = oral glucose tolerance test; TG = triglycerides; UL = upper limit

Table 12: Logistic regressions between food insecurity and diabetes risk factors in a lower-income (300% federal poverty line and below) sample of adolescents aged 12 - 19 years (n = 3412) in NHANES cycles 2007 - 2016

		Model 1				Model 2			
	N	Odds Ratio	95% CI LL	95% CI UL	P-value	Odds Ratio	95% CI LL	95% CI UL	P-value
HbA1C	3412								
Full food security		Ref.				Ref.			
Marginal food security		1.37	0.91	2.08	0.67	1.13	0.74	1.70	0.83
Food insecurity		1.61	1.10	2.36	0.06	1.37	0.95	1.98	0.12
P-for-trend					**0.01**				0.09
TG/HDL Ratio	1488								
Full food security		Ref.				Ref.			
Marginal food security		0.80	0.53	1.19	0.46	0.76	0.48	1.20	0.43
Food insecurity		0.85	0.60	1.21	0.79	0.82	0.57	1.19	0.74
P-for-trend					0.32				0.26
Fasting Plasma Glucose (mg/dL)	1507								
Full food security		Ref.				Ref.			
Marginal food security		1.01	0.58	1.77	0.94	1.01	0.58	1.76	0.93
Food insecurity		0.98	0.69	1.39	0.89	0.98	0.70	1.38	0.90
P-for-trend					0.92				0.93
HOMA-IR	1457								
Full food security		Ref.				Ref.			
Marginal food security		1.16	0.73	1.85	0.72	0.96	0.60	1.54	0.90
Food insecurity		1.16	0.85	1.60	0.58	0.98	0.70	1.37	0.97
P-for-trend					0.34				0.89
OGTT (mg/dL)	1323								
Full food security		Ref.				Ref.			
Marginal food security		0.75	0.33	1.72	0.31	0.64	0.27	1.49	0.18
Food insecurity		1.26	0.68	2.34	0.23	1.21	0.69	2.15	0.16
P-for-trend					0.51				0.56

* Statistically significant estimates at alpha = 0.05 are bolded.
All analyses were conducted using survey procedures that account for the complex survey design including the strata, clusters, and weights.
Model 1 is age- and sex-adjusted. Model 2 is adjusted for adolescent age, sex, race/ethnicity, vigorous recreational activity, moderate recreational activity, sedentary time; household respondent education, marital status, and income (linear and quadratic term).
The cut-points for HbA1C, fasting plasma glucose, and OGTT are based on clinical cut-points. The value of the cut-points for TG/HDL ratio and HOMA-IR are the 75th percentile of that biomarker in the broader adolescent population (i.e. all adolescents aged 12 - 19 years who had data on the biomarker and fasted for 9 - 24 hours).
According to the United States Department of Agriculture (USDA), full food security is defined as "no reported indications of food-access problems or limitations." Marginal food security is defined as "one or two reported indications—typically of anxiety over food sufficiency or shortage of food in the house. Little or no indication of changes in diets or food intake." Food insecurity is defined as "a household-level economic and social condition of limited or uncertain access to adequate food." These definitions are from the USDA Economic Research Service (ERS): https://www.ers.usda.gov/topics/food-nutrition-assistance/food-security-in-the-us/definitions-of-food-security.aspx
Abbreviations: CI = Confidence interval; HDL = high density lipoprotein; HOMA-IR = homeostatic model assessment - insulin resistance; LL = lower limit; mg/dL = milligram/deciliter; NHANES = National Health and Nutrition Examination Survey; OGTT = oral glucose tolerance test; OR = odds ratio; TG = triglycerides; UL = upper limit

Chapter 5 Conclusion

This dissertation examined associations between food insecurity and UPF acquisition/purchase, UPF intake, and diabetes risk factors in U.S. adolescents. Aim 1 examined the association between food insecurity and household SNAP participation with household UPF acquisitions/purchases for home consumption (as a percentage of total energy acquired/purchased for home consumption) in 3949 U.S. households and 1006 U.S. households with adolescents using the 2012 – 2013 FOODAPS dataset. Aim 2 examined the association between household food insecurity and household SNAP participation with UPF intake (as a percentage of total energy intake) in 3067 lower-income U.S. adolescents aged 12 – 19 years in the NHANES dataset, cycles 2007 – 2016. Finally, Aim 3 examined the association between household food insecurity and the diabetes risk factors of fasting plasma glucose (FPG), oral glucose tolerance (OGTT), hemoglobin A1C (HbA1C), homeostatic model assessment – insulin resistance (HOMA-IR), and triglyceride-to-high density lipoprotein cholesterol ratio (TG/HDL-c) in a sample of 3412 lower-income U.S. adolescents aged 12 – 19 years from the NHANES dataset, cycles 2007 – 2016. This chapter summarizes the results, necessary subsequent research, and public health implications for each aim. The interrelation between the aims is also discussed.

Aim 1 found that marginal food security was associated with higher household UPF acquisition/purchase for home consumption in U.S. households. High UPF acquisition/purchase, of course, likely plays a factor in UPF intake for marginally food secure individuals. The adjusted mean intake of UPFs as a percentage of total energy intake for lower-income adults with marginal food security is 53.6%. [62] UPFs – which have poor nutritional quality [152] and

possibly addictive characteristics [76] – have been associated with diabetes [65] and other chronic disease. [153] Therefore, research should examine reasons for higher UPF acquisition/purchase in this population. Programs and policies that improve acquisition/purchase for home consumption might positively impact UPF intake for individuals with marginal food security. Meanwhile, food insecurity and household SNAP participation were not associated with UPF acquisitions/purchasing for home consumption in U.S. households or U.S. households with adolescents. This differs from the literature on intake that has found that both food insecurity and household SNAP participation are associated with higher UPF intake in lower-income U.S. adults. [62] Future research should examine UPF acquired/purchased outside the home as well as other factors within the home (such as time scarcity [82]) that may facilitate disproportionately high UPF consumption. Regardless, adjusted means for UPF acquisition/purchase for home consumption were high for U.S. households and households with adolescents. Thus, all U.S. households could benefit from strategies that improve UPF acquisition/purchase for home consumption – particularly households with marginal food security.

Aim 2 found that food insecurity was not associated with UPF intake in a national sample of lower-income U.S. adolescents aged 12 – 19 years. This finding aligns with Aim 1 which found no association between food insecurity and household UPF acquisitions/purchases for home consumption for both U.S. households and households with adolescents. Across the food security spectrum, UPF acquisition/purchases for home consumption for U.S. households with adolescents and UPF intake in lower-income U.S. adolescents are very high. Therefore, improving UPF acquisitions, purchases, and intake in this population is still important. Additionally, although SNAP participation was not associated with higher UPF acquisition/purchase for home consumption in both U.S. households and U.S. households with

adolescents, it was found that SNAP is associated with higher UPF intake in both lower-income adolescents and lower-income U.S. adults. [62] As mentioned above, future research should examine potential reasons for this difference such as UPF acquisition/purchase outside the home and factors within the home such as time scarcity. [82] Qualitative work with lower-income adolescents that belong to SNAP-participating households is important to elucidate drivers of higher UPF intake in this age group. Finally, these findings have important public health implications as 1) lower-income adolescents are shown to have high UPF consumption across levels of food security and SNAP participation and 2) research has demonstrated that household SNAP participation is associated with higher UPF intake in both lower-income adults [62] and adolescents. Interventions that improve the quality of foods purchased with SNAP as well as UPF intake in lower-income U.S. adolescents would be beneficial.

Finally, Aim 3 found that household food insecurity was associated with higher HbA1C in lower-income U.S. adolescents aged 12 – 19 years. Two other studies had similar results. [43] [126] However, food insecurity was not associated with the other diabetes risk factors. Also, the mechanisms for this finding is not clear as no linkage between food insecurity and higher UPF intake was found (nor was UPF found to moderate the association between food insecurity and HbA1C). It is possible that food insecurity is associated with overconsumption of very specific food items such as sugar-sweetened beverages [34] which can increase diabetes risk [154] even if no other differences for UPF consumption or dietary quality may exist. It is important to note that the effect size of the finding was small (0.04%). However, food insecurity has been associated with higher diabetes risk in young adults [39] and in lower-income adults. [36] Research on the long-term effects of early instances of food insecurity and persistent food insecurity over the life-course could determine if this difference in HbA1C improves, persists, or

worsens over time. Interventions to improve food security in this age group would likely benefit diabetes risk as well as other critical aspects of health.

In light of the recent findings, it is unlikely that UPF acquisition/purchase, UPF intake, and diabetes risk is linked in lower-income U.S. adolescents; additionally, a few findings aligned with initial hypotheses while others did not. While connections between the aims do not exist and some findings were unexpected, the individual results still have important research and public health implications. It was found that marginal food security was associated with higher UPF acquisition/purchase for home consumption in U.S. households. Public health interventions that improve UPF acquisition/purchase for households with marginal food security may have a positive impact on UPF intake. Similarly, Aim 2 found that household SNAP participation was associated with higher UPF intake in lower-income U.S. adolescents – similar to an association found for lower-income U.S. adults. [62] Thus, public health interventions to improve UPF intake in SNAP participants is needed. Finally, food insecurity was associated with slightly higher HbA1C in lower-income adolescents. Interventions that improve food security in lower-income U.S. adolescents may improve SSB intake, HbA1C, and other health outcomes.

The strengths of this dissertation include the use of large national datasets to examine an understudied public health issue with important ramifications. The limitations include the use of observational cross-sectional data and the potential for bias through residual confounding and measurement error. Future research should examine the link between food insecurity, UPF acquisition/purchase, UPF intake, and diabetes risk in lower-income U.S. adults and other age groups such as emerging adults and older adults. Research has shown that food insecurity is associated with higher UPF intake [62] and higher diabetes risk [36] in lower-income U.S. adults; however, no research has examined if UPF acquisition/purchase away from home may

drive high UPF intake in this population nor if UPF intake mediates the association between food insecurity and diabetes risk. Finally, research examining these associations by race/ethnicity is also important.

Currently, no research has examined potential public health interventions that can improve associations between food insecurity, UPF acquisition/purchases, UPF intake, and diabetes risk in U.S. adolescents. However, research can determine if other interventions that have been shown to improve dietary quality and chronic disease risk in populations with food insecurity can improve UPF acquisition/purchases, UPF intake, and diabetes risk in lower-income adolescents. In the meantime, higher SNAP benefits [79] and fruit/vegetable incentive programs [109] have been shown to improve purchases and dietary quality so may improve UPF acquisition/purchasing and intake in lower-income U.S. households. Additionally, regulations that preclude the disproportionate marketing of UPFs to lower-income children and non-Hispanic Black children [5] may positively influence UPF acquisition/purchase and intake. Recently, the American Heart Association recommended universal free school meals and more robust nutrition standards as ways to improve dietary intake in lower-income children. [155] In the long-run, social and economic policies that improve financial security [156] and time scarcity [82] would likely improve these issues as well as several interconnected ones. To ensure health for populations with food insecurity, policies and programs across the socioecological model should work together to ensure access to unprocessed foods as well as sufficient time and resources to prepare them.

To conclude, food insecurity is a major public health issue in the United States. In U.S. adolescents, food insecurity has been associated with numerous debilitating health effects including psychological distress, [157] eating psychopathology, [158] substance use, [159]

mental health issues, [160] and suicidal behavior. [160] In adults, it has been associated with poor dietary quality [30] – including higher UPF intake [62] – and diabetes. [36] Food insecurity has also been associated with poorer quality food purchases [26] likely due to financial constraints. Prior to this dissertation, no research had examined the potential linkage between UPF acquisition/purchase, UPF intake, and diabetes risk factors in U.S. adolescents. This dissertation found associations between marginal food security and higher household UPF acquisition/purchase for home consumption, household SNAP participation and higher UPF intake in lower-income U.S. adolescents, and household food insecurity with higher HbA1C in lower-income U.S. adolescents. Although no causal link was found between food insecurity, UPF acquisition/purchase, UPF intake, and diabetes risk factors in U.S. adolescents, the independent associations discovered still bear great public health importance. Future quantitative and qualitative work should further examine the associations so that the appropriate public health interventions can be implemented. These associations point to an interrelated web of poverty, constraints around the accessibility of nutritious foods (such as time [82] and money), unfair UPF marketing to lower-income children and non-Hispanic Black children, [5] and the food industry's intentional development of food products that could be addictive [161] – most of which can be classified as UPFs. [9] These factors affect nutrition and compound chronic disease risk in populations that have been historically marginalized and exploited. As we adjust policies and programs to make reparations for these issues and promote nutrition equity, we will observe beneficial outcomes for our most vulnerable communities as well as the broader public.

Appendices

Appendix A

U.S. ADULT FOOD SECURITY SURVEY MODULE: [69]

THREE-STAGE DESIGN, WITH SCREENERS

Economic Research Service, USDA

September 2012

Revision Notes: The food security questions in the U.S. Adult Food Security Survey Module are essentially unchanged from those in the original module first implemented in 1995.

September 2012:

- Corrected skip specifications in AD5
- Added coding specifications for "How many days" for 30-day version of AD1a and AD5a.

July 2008:

- Wording of resource constraint in AD2 was corrected to, "…because there wasn't enough money for food" to be consistent with the intention of the September 2006 revision.

September 2006:

- Minor changes were introduced to standardize wording of the resource constraint in most questions to read, "…because there wasn't enough money for food."
- Question numbers were changed to be consistent with those in the revised Household Food Security Survey Module.

- User notes following the questionnaire were revised to be consistent with current practice and with new labels for ranges of food security and food insecurity introduced by USDA in 2006.

Overview: The U.S. Adult Food Security Survey Module is the same set of questions that is administered as the U.S. Household Food Security Survey Module to households with no child present. For many measurement purposes, the adult module can be used both for households with and without children present.

The U.S. Adult Food Security Survey Module is the same set of questions that is administered as the U.S. Household Food Security Survey Module to households with no child present. For many measurement purposes, the adult module can be used both for households with and without children present.

Advantages (compared with the 18-item household module):

Less respondent burden.

Improves comparability of food security statistics between households with and without children and among households with children in different age ranges.

Avoids asking questions about children's food security, which can be sensitive in some survey contexts.

Limitations:

Does not provide specific information on food security of children.

Transition Into Module (administered to all households):

These next questions are about the food eaten in your household in the last 12 months, since (current month) of last year and whether you were able to afford the food you need.

Optional USDA Food Sufficiency Question/Screener: Question HH1 (This question is

optional. It is not used to calculate the Adult Food Security Scale. It may be used in conjunction with income as a preliminary screener to reduce respondent burden for high income households).

HH1. [IF ONE PERSON IN HOUSEHOLD, USE "I" IN PARENTHETICALS, OTHERWISE, USE "WE."]

Which of these statements best describes the food eaten in your household in the last 12 months: —enough of the kinds of food (I/we) want to eat; —enough, but not always the kinds of food (I/we) want; —sometimes not enough to eat; or, —often not enough to eat?

[1] Enough of the kinds of food we want to eat

[2] Enough but not always the kinds of food we want

[3] Sometimes not enough to eat

[4] Often not enough to eat

[ ] DK or Refused

Household Stage 1: Questions HH2-HH4 (asked of all households; begin scale items).

[IF SINGLE ADULT IN HOUSEHOLD, USE "I," "MY," AND "YOU" IN PARENTHETICALS; OTHERWISE, USE "WE," "OUR," AND "YOUR HOUSEHOLD."]

HH2. Now I'm going to read you several statements that people have made about their food situation. For these statements, please tell me whether the statement was often true, sometimes true, or never true for (you/your household) in the last 12 months—that is, since last (name of current month).

The first statement is "(I/We) worried whether (my/our) food would run out before (I/we) got money to buy more." Was that often true, sometimes true, or never true for (you/your household) in the last 12 months?

[ ] Often true

[ ] Sometimes true

[ ] Never true

[ ] DK or Refused

HH3. "The food that (I/we) bought just didn't last, and (I/we) didn't have money to get more." Was that often, sometimes, or never true for (you/your household) in the last 12 months?

[ ] Often true

[ ] Sometimes true

[ ] Never true

[ ] DK or Refused

HH4. "(I/we) couldn't afford to eat balanced meals." Was that often, sometimes, or never true for (you/your household) in the last 12 months?

[ ] Often true

[ ] Sometimes true

[ ] Never true

[ ] DK or Refused

Screener for Stage 2 Adult-Referenced Questions: If affirmative response (i.e., "often true" or "sometimes true") to one or more of Questions HH2-HH4, OR, response [3] or [4] to question HH1 (if administered), then continue to ***Adult Stage 2;*** otherwise skip to ***End of Adult Food Security Module.***

NOTE: In a sample similar to that of the general U.S. population, about 20 percent of households (45 percent of households with incomes less than 185 percent of poverty line) will pass this screen and continue to Adult Stage 2.

<u>Adult Stage 2: Questions AD1-AD4</u> (asked of households passing the screener for Stage 2 adult-referenced questions).

AD1. In the last 12 months, since last (name of current month), did (you/you or other adults in your household) ever cut the size of your meals or skip meals because there wasn't enough money for food?

[ ] Yes

[ ] No (Skip AD1a)

[ ] DK (Skip AD1a)

AD1a. [IF YES ABOVE, ASK] How often did this happen—almost every month, some months but not every month, or in only 1 or 2 months?

[ ] Almost every month

[ ] Some months but not every month

[ ] Only 1 or 2 months

[ ] DK

AD2. In the last 12 months, did you ever eat less than you felt you should because there wasn't enough money for food?

[ ] Yes

[ ] No

[ ] DK

AD3. In the last 12 months, were you every hungry but didn't eat because there wasn't enough money for food?

[ ] Yes

[ ] No

[ ] DK

AD4. In the last 12 months, did you lose weight because there wasn't enough money for food?

[ ] Yes

[ ] No

[ ] DK

Screener for Stage 3 Adult-Referenced Questions: If affirmative response to one or more of questions AD1 through AD4, then continue to ***Adult Stage 3;*** otherwise, skip to ***End of Adult Food Security Module.***

NOTE: In a sample similar to that of the general U.S. population, about 8 percent of households (20 percent of households with incomes less than 185 percent of poverty line) will pass this screen and continue to Adult Stage 3.

Adult Stage 3: Questions AD5-AD5a (asked of households passing screener for Stage 3 adult-referenced questions).

AD5. In the last 12 months, did (you/you or other adults in your household) ever not eat for a whole day because there wasn't enough money for food?

[ ] Yes

[ ] No (Skip AD5a)

[ ] DK (Skip AD5a)

AD5a. [IF YES ABOVE, ASK] How often did this happen—almost every month, some months but not every month, or in only 1 or 2 months?

[ ] Almost every month

[ ] Some months but not every month

[ ] Only 1 or 2 months

[ ] DK

END OF ADULT FOOD SECURITY MODULE

User Notes

(1) Coding Responses and Assessing Household Adult Food Security Status:

Following is a brief overview of how to code responses and assess household food security status based on the Adult Food Security Scale. For detailed information on these procedures, refer to the *Guide to Measuring Household Food Security, Revised 2000,* available through the ERS Food Security in the United States Briefing Room.

Responses of "yes," "often," "sometimes," "almost every month," and "some months but not every month" are coded as affirmative. The sum of affirmative responses to the 10 questions in the Adult Food Security Scale is the household's raw score on the scale.

Food security status is assigned as follows:

- Raw score zero—High food security among adults
- Raw score 1-2—Marginal food security among adults
- Raw score 3-5—Low food security among adults
- Raw score 6-10—Very low food security among adults

For some reporting purposes, the food security status of the first two categories in combination is described as food secure and the latter two as food insecure.

(2) Response Options: For interviewer-administered surveys, DK ("don't know") and "Refused" are blind responses—that is, they are not presented as response options but marked if volunteered. For self-administered surveys, "don't know" is presented as a response option.

(3) Screening: The two levels of screening for adult-referenced questions are provided for surveys in which it is considered important to reduce respondent burden. In pilot surveys

intended to validate the module in a new cultural, linguistic, or survey context, screening should be avoided if possible and all questions should be administered to all respondents.

To further reduce burden for higher income respondents, a preliminary screener may be constructed using question HH1 along with a household income measure. Households with income above twice the poverty threshold AND who respond <1> to question HH1 may be skipped to the end of the module and classified as food secure. Using this preliminary screener reduces total burden in a survey with many higher income households, and the cost, in terms of accuracy in identifying food-insecure households, is not great. However, research has shown that a small proportion of the higher income households screened out by this procedure will register food insecurity if administered the full module. If question HH1 is not needed for research purposes, a preferred strategy is to omit HH1 and administer Adult Stage 1 of the module to all households.

(4) 30-Day Reference Period: The questionnaire items may be modified to a 30-day reference period by changing the "last 12-month" references to "last 30 days." In this case, items AD1a and AD5a must be changed to read as follows:

AD1a/AD5a. [IF YES ABOVE, ASK] In the last 30 days, how many days did this happen?

_____ days

[ ] DK

Responses of 3 days or more are coded as "affirmative" responses.

Appendix B

U.S. HOUSEHOLD FOOD SECURITY SURVEY MODULE: [69]

THREE-STAGE DESIGN, WITH SCREENERS

Economic Research Service, USDA

September 2012

Revision Notes: The food security questions are essentially unchanged from those in the original module first implemented in 1995 and described previously in this document.

September 2012:

- Corrected skip specifications in AD5
- Added coding specifications for "How many days" for 30-day version of AD1a and AD5a.

July 2008:

- Wording of resource constraint in AD2 was corrected to, "…because there wasn't enough money for food" to be consistent with the intention of the September 2006 revision.
- Corrected errors in "Coding Responses" Section

September 2006:

- Minor changes were introduced to standardize wording of the resource constraint in most questions to read, "…because there wasn't enough money for food."
- Question order was changed to group the child-referenced questions following the household- and adult-referenced questions. The Committee on National Statistics panel

that reviewed the food security measurement methods in 2004-06 recommended this change to reduce cognitive burden on respondents. Conforming changes in screening specifications were also made. NOTE: Question numbers were revised to reflect the new question order.

- Follow up questions to the food sufficiency question (HH1) that were included in earlier versions of the module have been omitted.
- User notes following the questionnaire have been revised to be consistent with current practice and with new labels for ranges of food security and food insecurity introduced by USDA in 2006.

Transition into Module (administered to all households):

These next questions are about the food eaten in your household in the last 12 months, since (current month) of last year and whether you were able to afford the food you need.

Optional USDA Food Sufficiency Question/Screener: Question HH1 (This question is optional. It is not used to calculate any of the food security scales. It may be used in conjunction with income as a preliminary screener to reduce respondent burden for high income households).

HH1. [IF ONE PERSON IN HOUSEHOLD, USE "I" IN PARENTHETICALS, OTHERWISE, USE "WE."]

Which of these statements best describes the food eaten in your household in the last 12 months: —enough of the kinds of food (I/we) want to eat; —enough, but not always the kinds of food (I/we) want; —sometimes not enough to eat; or, —often not enough to eat?

[1] Enough of the kinds of food we want to eat

[2] Enough but not always the kinds of food we want

[3] Sometimes not enough to eat

[4] Often not enough to eat

[ ] DK or Refused

Household Stage 1: Questions HH2-HH4 (asked of all households; begin scale items).

[IF SINGLE ADULT IN HOUSEHOLD, USE "I," "MY," AND "YOU" IN PARENTHETICALS; OTHERWISE, USE "WE," "OUR," AND "YOUR HOUSEHOLD."]

HH2. Now I'm going to read you several statements that people have made about their food situation. For these statements, please tell me whether the statement was often true, sometimes true, or never true for (you/your household) in the last 12 months—that is, since last (name of current month).

The first statement is "(I/We) worried whether (my/our) food would run out before (I/we) got money to buy more." Was that often true, sometimes true, or never true for (you/your household) in the last 12 months?

[ ] Often true

[ ] Sometimes true

[ ] Never true

[ ] DK or Refused

HH3. "The food that (I/we) bought just didn't last, and (I/we) didn't have money to get more." Was that often, sometimes, or never true for (you/your household) in the last 12 months?

[ ] Often true

[ ] Sometimes true

[ ] Never true

[ ] DK or Refused

HH4. "(I/we) couldn't afford to eat balanced meals." Was that <u>often</u>, <u>sometimes</u>, or <u>never</u> true for (you/your household) in the last 12 months?

[ ] Often true

[ ] Sometimes true

[ ] Never true

[ ] DK or Refused

<u>Screener for Stage 2 Adult-Referenced Questions:</u> If affirmative response (i.e., "often true" or "sometimes true") to one or more of Questions HH2-HH4, OR, response [3] or [4] to question HH1 (if administered), then continue to ***Adult Stage 2;*** otherwise, if children under age 18 are present in the household, skip to ***Child Stage 1,*** otherwise skip to ***End of Food Security Module.***

<u>NOTE:</u> In a sample similar to that of the general U.S. population, about 20 percent of households (45 percent of households with incomes less than 185 percent of poverty line) will pass this screen and continue to Adult Stage 2.

<u>Adult Stage 2: Questions AD1-AD4</u> (asked of households passing the screener for Stage 2 adult-referenced questions).

AD1. In the last 12 months, since last (name of current month), did (you/you or other adults in your household) ever cut the size of your meals or skip meals because there wasn't enough

money for food?

[ ] Yes

[ ] No (Skip AD1a)

[ ] DK (Skip AD1a)

AD1a. [IF YES ABOVE, ASK] How often did this happen—almost every month, some months but not every month, or in only 1 or 2 months?

[ ] Almost every month

[ ] Some months but not every month

[ ] Only 1 or 2 months

[ ] DK

AD2. In the last 12 months, did you ever eat less than you felt you should because there wasn't enough money for food?

[ ] Yes

[ ] No

[ ] DK

AD3. In the last 12 months, were you every hungry but didn't eat because there wasn't enough money for food?

[ ] Yes

[ ] No

[ ] DK

AD4. In the last 12 months, did you lose weight because there wasn't enough money for food?

[ ] Yes

[ ] No

[ ] DK

Screener for Stage 3 Adult-Referenced Questions: If affirmative response to one or more of questions AD1 through AD4, then continue to ***Adult Stage 3;*** otherwise, if children under age 18 are present in the household, skip to ***Child Stage 1,*** otherwise skip to ***End of Food Security Module.***

NOTE: In a sample similar to that of the general U.S. population, about 8 percent of households (20 percent of households with incomes less than 185 percent of poverty line) will pass this screen and continue to Adult Stage 3.

Adult Stage 3: Questions AD5-AD5a (asked of households passing screener for Stage 3 adult-referenced questions).

AD5. In the last 12 months, did (you/you or other adults in your household) ever not eat for a whole day because there wasn't enough money for food?

[ ] Yes

[ ] No (Skip AD5a)

[ ] DK (Skip AD5a)

AD5a. [IF YES ABOVE, ASK] How often did this happen—almost every month, some months but not every month, or in only 1 or 2 months?

[ ] Almost every month

[ ] Some months but not every month

[ ] Only 1 or 2 months

[ ] DK

Child Stage 1: Questions CH1-CH3 (Transitions and questions CH1 and CH2 are administered to all households with children under age 18) Households with no child under age 18, skip to ***End of Food Security Module.***

SELECT APPROPRIATE FILLS DEPENDING ON NUMBER OF ADULTS AND NUMBER OF CHILDREN IN THE HOUSEHOLD.

Transition into Child-Referenced Questions:

Now I'm going to read you several statements that people have made about the food situation of their children. For these statements, please tell me whether the statement was OFTEN true, SOMETIMES true, or NEVER true in the last 12 months for (your child/children living in the household who are under 18 years old).

CH1. "(I/we) relied on only a few kinds of low-cost food to feed (my/our) child/the children) because (I was/we were) running out of money to buy food." Was that often, sometimes, or never true for (you/your household) in the last 12 months?

[ ] Often true

[ ] Sometimes true

[ ] Never true

[ ] DK or Refused

CH2. "(I/We) couldn't feed (my/our) child/the children) a balanced meal, because (I/we) couldn't afford that." Was that often, sometimes, or never true for (you/your household)

in the last 12 months?

[ ] Often true

[ ] Sometimes true

[ ] Never true

[ ] DK or Refused

CH3. "(My/Our child was/The children were) not eating enough because (I/we) just couldn't afford enough food." Was that <u>often</u>, <u>sometimes</u>, or <u>never</u> true for (you/your household) in the last 12 months?

[ ] Often true

[ ] Sometimes true

[ ] Never true

[ ] DK or Refused

<u>Screener for Stage 2 Child Referenced Questions:</u> If affirmative response (i.e., "often true" or "sometimes true") to one or more of questions CH1-CH3, then continue to ***Child Stage 2;*** otherwise skip to ***End of Food Security Module.***

<u>NOTE:</u> In a sample similar to that of the general U.S. population, about 16 percent of households with children (35 percent of households with children with incomes less than 185 percent of poverty line) will pass this screen and continue to Child Stage 2.

<u>Child Stage 2: Questions CH4-CH7</u> (asked of households passing the screener for stage 2 child-referenced questions).

<u>NOTE:</u> In Current Population Survey Food Security Supplements, question CH6 precedes

question CH5.

CH4. In the last 12 months, since (current month) of last year, did you ever cut the size of (your child's/any of the children's) meals because there wasn't enough money for food?

[ ] Yes

[ ] No

[ ] DK

CH5. In the last 12 months, did (CHILD'S NAME/any of the children) ever skip meals because there wasn't enough money for food?

[ ] Yes

[ ] No (Skip CH5a)

[ ] DK (Skip CH5a)

CH5a. [IF YES ABOVE ASK] How often did this happen—almost every month, some months but not every month, or in only 1 or 2 months?

[ ] Almost every month

[ ] Some months but not every month

[ ] Only 1 or 2 months

[ ] DK

CH6. In the last 12 months, (was your child/were the children) ever hungry but you just couldn't afford more food?

[ ] Yes

[ ] No

[ ] DK

CH7. In the last 12 months, did (your child/any of the children) ever not eat for a whole day because there wasn't enough money for food?

[ ] Yes

[ ] No

[ ] DK

END OF FOOD SECURITY MODULE

User Notes

(1) Coding Responses and Assessing Household Food Security Status:

Following is a brief overview of how to code responses and assess household food security status based on various standard scales. For detailed information on these procedures, refer to the *Guide to Measuring Household Food Security, Revised 2000,* and *Measuring Children's Food Security in U.S. Households, 1995-1999.* Both publications are available through the ERS Food Security in the United States Briefing Room.

Responses of "yes," "often," "sometimes," "almost every month," and "some months but not every month" are coded as affirmative. The sum of affirmative responses to a specified set of items is referred to as the household's raw score on the scale comprising those items.

- Questions HH2 through CH7 comprise the U.S. Household Food Security Scale (questions HH2 through AD5a for households with no child present). Specification of food security status depends on raw score and whether there are children in the household (i.e., whether responses to child-referenced questions are included in the raw score).

- For households with one or more children:
    - Raw score zero—High food security
    - Raw score 1-2—Marginal food security
    - Raw score 3-7—Low food security
    - Raw score 8-18—Very low food security
- For households with no child present:
    - Raw score zero—High food security
    - Raw score 1-2—Marginal food security
    - Raw score 3-5—Low food security
    - Raw score 6-10—Very low food security

Households with high or marginal food security are classified as food secure. Those with low or very low food security are classified as food insecure.

- Questions HH2 through AD5a comprise the U.S. Adult Food Security Scale.
    - Raw score zero—High food security among adults
    - Raw score 1-2—Marginal food security among adults
    - Raw score 3-5—Low food security among adults
    - Raw score 6-10—Very low food security among adults
- Questions HH3 through AD3 comprise the six-item Short Module from which the Six-Item Food Security Scale can be calculated.
    - Raw score 0-1—High or marginal food security (raw score 1 may be considered marginal food security, but a large proportion of households that

would be measured as having marginal food security using the household or adult scale will have raw score zero on the six-item scale)

- Raw score 2-4—Low food security
- Raw score 5-6—Very low food security

- Questions CH1 through CH7 comprise the U.S. Children's Food Security Scale.
    - Raw score 0-1—High or marginal food security among children (raw score 1 may be considered marginal food security, but it is not certain that all households with raw score zero have high food security among children because the scale does not include an assessment of the anxiety component of food insecurity)
    - Raw score 2-4—Low food security among children
    - Raw score 5-8—Very low food security among children

(2) Response Options: For interviewer-administered surveys, DK ("don't know") and "Refused" are blind responses—that is, they are not presented as response options, but marked if volunteered. For self-administered surveys, "don't know" is presented as a response option.

(3) Screening: The two levels of screening for adult-referenced questions and one level for child-referenced questions are provided for surveys in which it is considered important to reduce respondent burden. In pilot surveys intended to validate the module in a new cultural, linguistic, or survey context, screening should be avoided if possible and all questions should be administered to all respondents.

To further reduce burden for higher income respondents, a preliminary screener may be

constructed using question HH1 along with a household income measure. Households with income above twice the poverty threshold, AND who respond <1> to question HH1 may be skipped to the end of the module and classified as food secure. Use of this preliminary screener reduces total burden in a survey with many higher-income households, and the cost, in terms of accuracy in identifying food-insecure households, is not great. However, research has shown that a small proportion of the higher income households screened out by this procedure will register food insecurity if administered the full module. If question HH1 is not needed for research purposes, a preferred strategy is to omit HH1 and administer Adult Stage 1 of the module to all households and Child Stage 1 of the module to all households with children.

(4) 30-Day Reference Period: The questionnaire items may be modified to a 30-day reference period by changing the "last 12-month" references to "last 30 days." In this case, items AD1a, AD5a, and CH5a must be changed to read as follows:

AD1a/AD5a/CH5a [IF YES ABOVE, ASK] In the last 30 days, how many days did this happen?

_____ days

[ ] DK

Responses of 3 days or more are coded as "affirmative" responses.

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