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Food Insecurity in Youth and Young Adults With Diabetes: Prevalence and Association With Health Behaviors

Lauren Helene Martini

FOOD INSECURITY IN YOUTH AND YOUNG ADULTS WITH DIABETES: PREVALENCE AND ASSOCIATION WITH HEALTH BEHAVIORS

by

Lauren Helene Martini

Bachelor of Science
University at Albany, State University of New York, 2009

Master of Public Health
Columbia University, 2011

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Arnold School of Public Health

University of South Carolina

Accepted by:

Angela D. Liese, Major Professor

Anwar T. Merchant, Committee Member

Alexander C. McLain, Committee Member

Jason A. Mendoza, Committee Member

Cheryl Addy, Interim Vice Provost and Dean of the Graduate School

ABSTRACT

Given the life-long impact of diabetes(1-5), it is important to engage in behaviors that promote health and wellness to delay or prevent negative health outcomes(3, 6-10). Despite this, youth and young adults with diabetes generally do not adhere to nutritional(11-17) or physical activity(18, 19) recommendations. In households experiencing financial difficulties, especially those who are having difficulty providing sufficient food to all of its members, adhering to recommendations may be even more difficult.

The purpose of this dissertation is to better understand and contextualize food insecurity among youth and young adults (YYA) with youth-onset T1DM and T2DM. The first aim addresses this by estimating the prevalence of food insecurity by diabetes type and age group. The second aim extends this by analyzing the effect of food insecurity on lifestyle behaviors, namely dietary quality and electronic media use.

In this population of YYA with T1DM and T2DM, 21.4% experienced food insecurity, including 7.6% reporting very low food security (Table 4.1). This is higher than comparable population-based estimates for both food insecurity (United States - US: 12.7%; South Carolina – SC: 13.2%; Washington – WA: 12.9%) and very low food security (US: 5.4%; SC: 4.6%; WA: 4.8%)(20). Food insecurity was more common among participants with T2DM (36.8%; 95% CI: 26.9-48.1) compared to those with T1DM (17.2%; 95% CI: 13.2-22.1; Table 4.2), and the proportion of participants experiencing

very low food security was almost double (T2DM: 11.8%; T1DM: 6.5%; Table 4.1). While there is some evidence to suggest that there might be age-related trends (Table 4.2; T1DM: <17 years: 14.4%, 18+ years: 19.0%; T2DM: <17 years old: 39.3%, ≥18 years: 35.4%), these were not statistically significant, likely due to the small sample size and the relationship between diabetes type and age.

With respect to the two lifestyle outcomes, there was limited support for a relationship between food security and either dietary quality (Tables 4.4-4.9) or electronic media use (Tables 4.11-4.13). The findings do suggest the possibility of an underlying relationship, specifically the relationship between food insecurity and high-level electronic media use outcomes (Table 4.13).

Due to the nature of diabetes and diabetes management strategies, food security is especially important in this population. However, the findings suggest that the increased budgetary demands associated with the management chronic diseases, such as diabetes, are having negative effects within these households. These findings suggest that an intervention, e.g., providing financial, food, medication, or other related assistance, may be especially effective among YYA with diabetes. The disparities in food insecurity by diabetes type and the trends related to age, although not statistically significant, are concerning. The overarchingly poor dietary intake quality and electronic media habits is especially troubling, given the role of healthful behaviors in effective diabetes management.

In conclusion, in this cohort of youth and young adults with diabetes, almost 1 in 3 YYA with diabetes (32.4%) was living in a household that had some level of concern about having enough money for food and more than 1 in 5 participants (21.4%) experienced food

insecurity. More than double the participants with T2DM (36.8%; 95% CI: 26.9-48.1) reported experiencing food insecurity compared to participants with T1DM (17.2%; 95% CI: 13.2-22.1), trends that were similar regardless of age group. Although findings related to behavioral outcomes are inconsistent, there is some evidence to suggest that there are trends in both dietary quality and electronic media use. Given the important downstream implications, it is exceptionally important to work toward supportive interventions that reduce food insecurity among YYA with T1DM and T2DM.

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List of Abbreviations

AOR .... Adjusted Odds Ratio

CI .... Confidence Interval

FIS .... Food Insecure

FS .... Food Secure

HFSSM .... Household Food Security Status Module

OR .... Odds Ratio

RQ .... Research Question

SA .... Specific Aim

SC .... South Carolina

SD .... Standard Deviation

T1DM .... Type 1 Diabetes Mellitus

T2DM .... Type 2 Diabetes Mellitus

US .... United States

WA .... Washington

YYA .... Youth and Young Adults

CHAPTER 1: INTRODUCTION

1.1 Background

Globally, the United States continues to rank comparatively high for diabetes incidence, both T1DM(21, 22) and T2DM(22). This, despite continuing to spend drastically more on related health expenses(21, 22). In 2018, 34.2 million Americans were living with diabetes in the United States(22, 23). While a majority of cases in adults are Type 2 diabetes(4, 22-25), most cases in children and youth are Type 1 diabetes(22, 23, 26-28). According to recent estimates, there are 210,000 children and adolescents in the United States living with diagnosed diabetes, including 187,000 with Type 1(23).

Diagnosis of diabetes will have life-long effects(1-5). It is important to engage in healthy behaviors such as a healthy diet, regularly engaging in exercise, and adhering to the prescribed medication regimen to delay or prevent negative health outcomes(3, 6-10). Despite this, youth and young adults with diabetes generally do not adhere to nutritional(11-17) or physical activity(18, 19) recommendations. In households experiencing financial difficulties, especially those who are having difficulty providing sufficient food to all of its members, adhering to recommendations may be even more difficult.

According to the Unites States Department of Agriculture, there were 13.5 million households in the United States that experienced food insecurity during 2021 including 4.6 million with children(29). Food insecurity has been decreasing over the last decade, only

returning to rates similar to those prior to the Great Recession in the last few years(29). However, there is some evidence to suggest food insecurity may be increasing, likely due to high cost of living increases in combination with reduced support(30).

Households experiencing food insecurity often report coping strategies such as reducing overall food consumption, cutting meals, and relying on low-cost foods(31). Food insecure households report lower fruit and vegetable consumption(32-38), higher energy density(32, 38, 39) and increased reliance on carbohydrates(32, 39) than food secure households. In households experiencing food insecurity, there is often a tradeoff between buying food and paying rent, electricity, and heating bills. In households where a member has a chronic illness, this may also lead to medication underuse and delaying prescriptions refills(40, 41). In households where access to high quality food and medication are required for proper disease management, such as children with T1DM or T2DM, this could be especially problematic.

While younger children are typically shielded from food insecurity(31), youth and young adults with diabetes may cause an additional strain on household resources. Diabetes-related medication and medical appointments, purchasing and preparing food to ensure high quality meals, and the knowledge and attention required to keep youth and young adults with diabetes healthy is time, energy, and financially expensive for families.

Coping mechanisms often used by households experiencing food insecurity may lead to worse diabetes-related outcomes. Food insecure households may make changes to meal quantity or reduce the quality of meal content(33, 42, 43), prolong time between medication use(40, 44-46), and experienced increased stress(47, 48), all of which will have

a negative effect in populations with diabetes(40, 44, 46, 49-61). It is therefore important to better understand food insecurity in populations of youth and young adults with diabetes.

1.2 Study Population

The SEARCH for Diabetes in Youth is a large, multi-center study aiming to characterize the epidemiology of Type 1 (T1DM) and Type 2 (T2DM) Diabetes Mellitus in youth and young adults who were 20 years or younger at time of diagnosis. SEARCH began in 2000 and continues to date in five states: South Carolina, Ohio, Colorado, California, and Washington. Between 2013 and 2015, the SEARCH sites in South Carolina and Washington, participated in a pilot study on food security. These data serve as the basis of this dissertation.

1.3 Specific Aims and Research Questions

Specific Aim 1 (SA1) describes the prevalence of food insecurity in households in a sample of youth and young adults (YYA) with type 1 and type 2 diabetes. SA1 addresses the following two research questions (RQ):

1. Is the prevalence of household food insecurity higher in households with youth and young adults with type 2 diabetes compared to those with type 1 diabetes?
2. Is the prevalence of household food insecurity higher in households with youth compared to young adults with diabetes, stratified by participant sex and diabetes type?

Specific Aim 2 (SA2) evaluates the association between food insecurity and health related behaviors, specifically dietary quality and electronic media engagement. SA2 addresses the following two research questions (RQ):

1. Do youth and young adults with diabetes from households with food insecurity have poorer diet quality?
2. Do youth and young adults with diabetes from households with food insecurity spend more time engaging with electronic media, specifically television watching and leisure time computer use?

Chapter 2: Background

2.1 Diabetes

2.1.1 Overview

Diabetes refers to a group of complex, chronic, metabolic diseases that lead to hyperglycemia. Worldwide, more deaths are attributed to diabetes than HIV/AIDS, tuberculosis, and malaria(21). There are several types of diabetes including type 1, type 2, gestational, monogenic, and cystic-fibrosis-related. The focus henceforth will be on Type 1 (T1DM) and Type 2 (T2DM) diabetes mellitus.

1. Diabetes is screened in the general population using a finger-prick test, but more intensive blood glucose tests are required for diagnosis(62). The diagnostic criteria for diabetes is as follows: Fasting plasma glucose of 126 mg/dL (7.0 mmol/L) or higher,
2. Two-hour plasma glucose of 200 mg/dL (11.1 mmol/L) or higher during a 75-g oral glucose tolerance test,
3. A1C of 6.5% or higher, or;
4. In a patient with hyperglycemia or hyperglycemic crisis, a random plasma glucose of 200 mg/dL (11.1 mmol/L) or higher.

T1DM is among the most common chronic illnesses affecting children(63). Annually, it is estimated that there are about 18,000 incident cases of T1DM among youth under 20 years old in the United States (US)(4, 23). In 2009, 1.93 per 1000 US youth were

affected by T1DM(64), which increased to 2.15 per 1000 by 2017(65). T1DM is caused by an autoimmune reaction destroying the cells that produce insulin(16, 62). Since insulin cannot be produced, exogenous insulin is required to control blood sugar levels(16, 25).

Generally, the onset of T1DM is sudden(62). Symptoms include abnormal thirst and dry mouth, increased urination, mood changes, hunger, and unintended weight loss(25, 62). Almost one-third of new T1DM cases present with diabetic ketoacidosis (DKA)(66), a serious complication that can have long term consequences for neurocognitive development and function(49, 67-70). Despite the severe consequences of T1DM, it can be managed. Successful T1DM management includes careful attention to blood glucose levels, strict adherence to an appropriate insulin regimen, and a healthy lifestyle including a healthful diet and physical activity(49, 62).

Of the 34.2 million Americans with diabetes(23), T2DM accounts for 90-95% of cases(4, 24, 25). While mostly diagnosed in adults, T2DM is becoming increasingly common among children and adolescents(49, 71) and is expected to continue(26, 49, 64). Projections estimate that the number of youth with T2DM will quadruple by 2050(26), a trend that is supported by recent publications(23, 65).

In contrast to T1DM, those with T2DM can produce insulin, but insulin resistance prevents glucose from being properly regulated(25, 62). The onset and progression of T2DM is typically less severe than T1DM(62), often a significant period of time will pass before symptoms are noticeable(25, 62). However, youth-onset T2DM often progresses more rapidly than T2DM in adults(49, 72, 73). In youth with T2DM, cardiovascular risk factors and comorbidities may already be present at diagnosis(49, 72, 74).

Management of T2DM should involve eating a balanced diet, exercising regularly, and maintaining a healthy weight, as well as incorporating insulin into the treatment, as needed. These recommendations are similar to those for populations with T1DM. However, youth with T2DM may also require treatment with metformin to be sure to address any comorbidities(49).

2.1.2 Epidemiology of Diabetes

By 2040, an estimated 642 million people will have diabetes(21), but this is most likely an underestimate(22, 75-78). Despite improvements in awareness and treatments, many countries lack effective prevention programs(21). The most recent estimates suggest that there are 537 million adults with diabetes worldwide(22, 78), almost half of whom are undiagnosed(21, 22). Although T2DM accounts for most diabetes cases(22, 23), in 2022, there were 8.75 million people were living with T1DM globally, including 1.52 million children(28). Of the estimated 530,000 new T1DM diagnoses, less than half (n=201,000) occurred in people under 20 years old(28).

The US continues to rank high globally in diabetes burden, for both T1DM(21, 22) and T2DM(22), despite continuing to spend drastically more on related health expenses(21, 22). In the US, 34.2 million people had diabetes in 2018(23), predominantly T2DM(4, 23-25). Of these, 7.3 million adults, or 1 in 5 adults were diabetes, were living undiagnosed(23). If the present trend continues, as many as 1 in 3 Americans will have diabetes by 2050(79).

The global diabetes prevalence, mostly T2DM(4, 21, 25), has increased substantially(80). Potential explanations for the increased prevalence include population growth(25, 81), global aging(25, 81), and increases in the prevalence of associated

cardiovascular risk factors including obesity(82). Additionally, people with T1DM(83, 84) and T2DM(85) are living longer as a result of improvements in prevention(7, 8), screening(62, 86), and treatment(3, 7, 49, 87-90) options have led to people with diabetes living longer diabetes-related health outcomes. All of these will continue to cause the prevalence of T1DM and T2DM to increase worldwide. Compounding the issue, the incidence of T1DM and T2DM in youth and young adults has been steadily increasing(26, 91).

2.1.3 Epidemiology of Diabetes among Children, Youth, and Young Adults

Type 1 diabetes is among the most common chronic diseases of childhood(27). In 2021, there were approximately 1.2 million children and youth living with T1DM worldwide(21, 28). While T1DM accounts for most of diabetes cases among children and adolescents, T2DM is becoming more common among children and adolescents globally(22, 23, 91).

The US continues to rank among the countries with the highest incidence of both T1DM(21, 22) and T2DM(22). In 2018, approximately 210,000 children and adolescents under 20 years old in the US were living with diabetes, including an estimated 187,000 with T1DM and 23,000 with T2DM(23, 64).

The prevalence of both T1DM and T2DM has significantly increased over time(22, 23, 65, 92-96) and is expected to continue to increase(26). In children and youth, T1DM increased from 1.48 per 1000 in 2001 to 1.93 per 1000 in 2009(65, 71) and, more recently, 2.15 per 1000 in 2017(65). During this time, T2DM increased from 0.34 per 1000 in children and youth in 2001(65, 71) to 0.46 per 1000 in 2009(65, 71) and 0.67 per 1000 in 2017(65). Annually, the incidence of T1DM increased an average of 1.8% compared to

4.8% for T2DM(91). By 2050, 587,488 and 84,131 children and adolescents are projected to be living with T1DM and T2DM, respectively(26).

The number of children and adolescents living with diabetes is expected to continue to increase(26, 65). Much of this can be explained by implementation of screening procedures(62, 86), and increases in longevity and lifespan(24, 86) due to promotion of effective lifestyle and medical treatment(3, 7, 8, 49, 87-90, 97), however the increases in incidence of both T1DM and T2DM in US youth and young adults(91-96, 98) is particularly troubling. Youth-onset T2DM has a distinct presentation, including more complications, from both T1DM(99-101) and those diagnosed at older ages with T2DM(102, 103). Similar, although to a lesser extent, adult diagnosis of T1DM also has additional challenges(28). As diabetes is increasingly diagnosed in younger age groups and the population continues to age, the magnitude and the continuing growth of the population living with diabetes presents a unique public health challenge(26).

2.1.4 Potential Risk Factors and Correlates of Diabetes

There is little known about the cause or prevention of T1DM(21, 25, 62). In comparison, T2DM is much better understood. Familial clustering suggests that there is a genetic component of both T1DM(104, 105) and T2DM(106), but does not explain all of the variation(105, 106). Rather, it is widely accepted that there are both genetic and environmental factors, and their interaction, that lead to the development of T1DM(62, 105) and T2DM(106).

2.1.4.1 Familial Clustering and Genetics

Family history is an important risk factor for diabetes(107-109). The presence of either type of diabetes among family members is a risk factor for both T1DM(107, 108)

and T2DM(108, 109). The probability of being diagnosed with diabetes increases as the number of family members and degree of closeness in their relationship increases(107, 110). This association is independent of related sociodemographic and lifestyle characteristics such as BMI, race and ethnicity, and education(109, 110), suggesting that there must be a biological explanation for the observed clustering.

There has been some success identifying the genetic components of T1DM. Studies have identified 18 regions on the genome that can be linked to T1DM(111), a majority of which are located in the HLA region(104, 111). While some combinations are associated with increased risk for diabetes, others are protective(104, 111). Thus far, the strongest associations are between the DRB1-DQA1-DQB1 loci(104). In some cases, single gene mutations are the cause of T1DM, but these are rare(105).

The genetic components of T2DM have been less easy to identify. While several loci have been associated with increased risk of T2DM they are representative of only a small proportion of people who eventually are diagnosed with T2DM(106).

2.1.4.2 Age

There are age-related trends in both T1DM and T2DM(62, 112). The vast majority of diabetes cases among adults are T2DM and prevalence increases with age(4, 22, 23). Among children, T1DM is more common among children(63, 98, 113). T1DM can be diagnosed at birth and continues well into adulthood(98, 114). However, the incidence is highest during puberty, around 10-14 years old(98, 114).

Age at diagnosis is also associated with disease progression and severity. Those who are younger at diagnosis tend to have poorer health outcomes. While this is true for both T1DM(114) and T2DM(102), it may be a function of other factors including disease

duration, poor diabetes management among those with diabetes at younger ages, or those who get diabetes at younger ages may be inherently sicker than those who get diabetes at older ages.

2.1.4.3 Race and Ethnicity

Diabetes is associated with race and ethnicity. Among youth, T1DM is more common among non-Hispanic white youth than any other racial and ethnic groups(64, 114-116). In contrast, racial and ethnic minorities have a disproportionately higher prevalence of T2DM(62, 102, 117, 118), including among youth and young adults(92, 93, 95). T2DM is most common among American Indian and Alaskan Native youths(64).

Compounding the problem, racial and ethnic minorities receive poorer access to high quality care, despite accounting for other factors such as insurance and income(119). The prevalence of complications among youth and young adults with T1DM seem to be slightly more common in racial and ethnic minorities compared to non-Hispanic whites for most complications(74, 92, 93).

2.1.4.4 Socioeconomics

Socioeconomics is associated with diabetes. T1DM is associated with socioeconomic indicators such as higher income and high education(115, 120). However, those with lower educational attainment and income are at increased risk for comorbidities(121) and mortality(121). In contrast, lower socioeconomic status including income, education, and occupation has consistently been shown to be a predictor of T2DM(102, 122, 123). Low maternal income at birth was shown to be significantly associated with childhood-onset T2DM(124).

2.1.4.5 Other Environmental and Behavioral Exposures

The primary modifiable behavioral risk factor for T2DM in adults and children is being overweight(7, 8, 62, 125, 126). As a result, poor diet(7, 8, 25), low physical activity(7, 8, 25, 62, 102), and other metabolic risk factors(25, 62, 127) are also risk factors for T2DM. There is evidence to suggest a dose-response relationship between physical activity and increased metabolic risk(128, 129), even when accounting for body fat(129).

Breast feeding has a number of long-term health benefits for children, including reducing the likelihood of being diagnosed with diabetes or another chronic disease(130, 131). Early introduction to the bovine insulin in cow's milk may cause insulin binding antibodies to adapt leading to increased risk of T1DM and T2DM. Results are inconsistent among populations with T1DM(132), potentially due to genetic advantages or susceptibilities in study populations(133), the study period was not sufficient, misdiagnosis of diabetes type(134), validity issues of dietary intake assessments(135-137), or formula feeding may be more common among populations who are already at increased risk for diabetes. Comparatively, the association between breastfeeding and T2DM has been much better established(124, 138, 139).

In the past, there was substantial support for environmental risk factors. There were a number of theories regarding exposure to viruses, in utero or early childhood, causing T1DM(132, 140, 141). However, recent work has suggested that this may be inconclusive(140). In contrast, arsenic contamination of food and water is associated with T1DM and T2DM(142-145). In youth, arsenic exposure has been shown to be associated with T1DM in youth, but not T2DM(146).

There are a number of gestational and early life exposures that have been linked to diabetes in youth including maternal overweight(139, 147-149), maternal diabetes or gestational diabetes(124, 139, 147, 148, 150), and high(151) or low birthweight(139, 152, 153). In utero exposure to maternal obesity is associated with increased odds of T1DM(148, 149) and youth-onset T2DM(139, 147).

In general, obesity is closely tied to diabetes(118, 148, 154). This includes both maternal T2DM preexisting pregnancy and gestational diabetes(118, 148, 154). Youth and young adults with T1DM(148, 150) and T2DM(124, 139, 147) more often had some in utero exposure to diabetes. Compared to those who experienced no diabetes in utero, the odds of youth-onset T2DM was elevated among those who experienced gestational diabetes (OR: 4.3-4.3) and even higher among those whose mother had diabetes before pregnancy(OR: 5.8-14.4)(124, 139). Exposure to both maternal obesity and any diabetes, which are fairly common comorbidities, in utero is associated with a much greater increase in odds of child-onset T2DM(147).

2.1.5 Prevention of Diabetes

There are currently no prevention guidelines for T1DM(25). Researchers are evaluating prevention methods to delay and prevent T1DM onset and progression in populations with elevated risk genotypes. Thus far, interventions to prevent or delay the effects of T1DM were not successful(155, 156). Currently, diabetes management and control are the best options for the living with T1DM.

In contrast, T2DM is much better understood. While there is still no way to definitively prevent T2DM, there is a large body of evidence supporting the efficacy of lifestyle interventions(157). Diet and exercise are consistently shown to prevent or delay

T2DM(8, 21), particularly participating in a support program that targets weight loss like the Diabetes Prevention Program(158, 159). Pharmaceutical interventions, such as Metformin, have also been proven effective(8).

2.1.6 Complications

Diabetes is associated with severe short (i.e., acute) and long-term (i.e., chronic) complications. These complications often occur in adults, but are frequent among youth and young adults who were diagnosed in childhood(74). In 2014, approximately 7,155,000 hospital discharges and 14,192,000 emergency department visits among US adults included diabetes as a diagnosis(4).

Acute complications of diabetes include hypoglycemia, hyperglycemia, diabetic ketoacidosis (DKA), and hyperosmolar hyperglycemic state (HHS). Hypoglycemia occurs when blood glucose levels are significantly low. The onset of hypoglycemia can occur very quickly, usually as a result of behaviors that decrease blood glucose too quickly, such as taking too much insulin or excessive exercise, or by not obtaining sufficient dietary glucose. Symptoms of hypoglycemia can often go unnoticed, but increase in severity over time and may ultimately lead to loss of consciousness and death, if left untreated. In contrast, hyperglycemia occurs when blood sugar becomes significantly elevated because of lack of insulin. Extended hyperglycemia leads to the presence of ketones in the blood and urine resulting in DKA and HHS.

Chronic complications severely affect how people with diabetes can live their lives(5). Microvascular complications are those that affect the small blood vessels(5). These include retinopathy, nephropathy, and neuropathy. Diabetes is a leading cause of blindness(5, 160) and end stage renal disease(5, 161), slightly more than one-third of

people with diabetes have kidney disease(4). Macrovascular complications are those that affect the large blood vessels(5). These include ischemic heart disease, peripheral vascular disease, and cerebrovascular disease(5). The risk of cardiovascular events is two to three times higher in people with diabetes compared to people without diabetes(162, 163).

In youth and young adults with diabetes, complications were quite frequent overall. However, the odds were higher among those with T2DM compared to those with T1DM(74). Youth and young adults with T2DM may be at increased risk for complications. Youth at increased risk of T2DM generally have obesity, high blood pressure, dyslipidemia, and adiposity(126). As a result, those with younger onset T2DM typically have other cardiovascular risk factors and comorbidities when diagnosed with diabetes or shortly thereafter(164-167).

Effective diabetes management is essential to prevent complications. Evidence suggests that poor glycemic control is potentially the strongest predictor of complications(168). Therefore, maintaining blood glucose is essential to prevent and control long-term complications, especially among those with early onset diabetes(74, 103).

2.1.7 Diabetes Treatment Recommendations

The ADA recommends that individuals diagnosed with diabetes receive medical care from a team taking a collaborative and integrated approach. It is important that those with diabetes maintain a key role in their treatment and advocate for their needs. Effective diabetes treatment includes education and pharmacological interventions, as needed, to improve diabetes management capabilities. Effective diabetes management will improve

glycemic control and requires careful attention to diet and physical activity(6, 7, 62, 87-90).

2.1.7.1 Glycemic Control

Maintaining blood glucose is the most effective way to delay or prevent complications(21). There are two primary methods to monitor glycemic control: patient self-monitoring of blood glucose and A1C in a health care setting. Self-monitoring blood glucose is an effective component of diabetes treatment plans, and there is some evidence that increased frequency of self-monitoring is associated with better glycemic control. This allows people to evaluate and adjust lifestyle and pharmaceutical factors to meet glycemic targets and prevent hyperglycemia and hypoglycemia, which is especially important for those using insulin. In contrast, A1C will gauge whether individuals are meeting and maintaining their glycemic targets over several months. A1C tests are performed in a clinical setting several times a year, depending on the glycemic control of the individual. For most adults, A1C<7% is considered to be a reasonable goal(88). In children, A1C<7.5% is recommended(49).

2.1.7.2 Lifestyle Management

Lifestyle management is essential to effective diabetes management. Lifestyle management includes diabetes self-management education and support, nutrition therapy, physical activity, smoking cessation counseling, and psychosocial care(7). Diabetes self-management and support are ongoing programs where providers enable patients to make informed decisions regarding self-care and improve diabetes outcomes. Participation has been shown to improve self-management, clinical outcomes, health status, and quality of life(7).

2.1.7.2.1 Nutrition Therapy

Since nutrition is an exceptionally important aspect of diabetes management, nutrition therapy is intended to help people with diabetes navigate dietary decisions and create food plans. There are no universal dietary recommendations for people with diabetes, guidance is similar to the general population. Rather, nutrition therapy emphasizes healthy eating and promotes appropriately portioned, high-quality, nutrient-dense foods. The goals of nutrition therapy are to meet clinical goals regarding weight loss, glycemic control, blood pressure, lipids, and delaying or preventing complications(7). For persons with T1DM, carbohydrate counting is a key element of nutrition therapy(7).

2.1.7.2.2 Physical Activity Recommendations

Exercise has been shown safe and effective in most people who have diabetes that is well-controlled. The physical activity recommendations for adults and children with diabetes are similar to the general population. Adults are recommended to participate in 150 minutes or more of moderate to vigorous physical activity each week. In some cases, 75 minutes per week of vigorous aerobic physical activity may be an adequate substitute. These sessions should be spread over at least three days each week with no more than two consecutive days without physical activity. Resistance training two to three times per week and breaking up extended periods of sedentary behavior are also recommended. For children and adolescents, 60 minutes or more per day should be spent on moderate or vigorous physical activity. Strength training should be incorporated into exercise at least three days per week and sedentary activity should be decreased(7, 169, 170).

Particularly in those with T1DM, exercise-induced hypoglycemia is an added concern. As a result, additional precautions should be taken. Glucose should be monitored

before and after physical activity, changes indicate that additional food be consumed or insulin be administered. Carbohydrates should be consumed beforehand to avoid hypoglycemia and should be available during and after physical activity. Activity should be tailored to glycemic responses and avoided if glucose is too high with or without ketosis(7, 169, 170).

2.1.8 Dietary Intake and Quality among Children, Youth and Young Adults with Diabetes

Despite increased cardiovascular risk, youth and young adults generally do not adhere to dietary recommendations. Close adherence to dietary management has been shown to correlate with better glycemic control in youth with T1DM(16).

Youth with T1DM(16, 17) and T2DM(171) consume significantly less fruits and vegetables per day than recommended. However, youth with T1DM generally adhere to the recommendation regarding carbohydrate intake and may consume fewer sugar sweetened beverages than matched controls(16). Youth with T2DM rarely meet recommendations regarding saturated fat(171).

Older youth with diabetes(12), especially T2DM(12), tend to drink more sugar sweetened beverages compared to those with diabetes who are younger. Drinking soda more frequently has been shown to be associated with increased triglycerides, total cholesterol, and LDL cholesterol in youth and young adults with T1DM(15), including diet-beverages(13).

2.1.8.1 Dietary Quality in the SEARCH for Diabetes in Youth Cohort

To measure dietary intake, the SEARCH for Diabetes in Youth Study uses a modified food frequency questionnaire(17, 172). This modified food frequency

questionnaire has been shown to measure dietary intake reasonably well in this population(172) and has been used in other populations of youth with diabetes(171).

The proportion of the SEARCH for Diabetes in Youth Study population who met the nutritional guidance was low overall(15, 17). Those who met dietary recommendations included 19.4% fruit, 13.5% vegetable, 6.2% grain, 10.6% total fat, and 6.5% saturated fat(17). In a subsequent study, higher adherence to the Dietary Approaches to Stop Hypertension (DASH) diet was associated with substantial increases in consumption of nuts and seeds, and almost twice the fruit and low-fat dairy consumption compared to the lowest adherence(15).

Among youth and young adults with T1DM, males consumed fewer fruits, vegetables, and fiber, but more soda and saturated fat than females(12). Similarly, older participants reported lower dairy and calcium intake than younger participants(12). African American youth report lower dairy and calcium intake, but higher amounts of soda compared to non-Hispanic Whites(12). Among participants with T2DM, Native American youths reported consuming less dairy, fewer calories from saturated fat, and more vegetables, total fiber, and soda than those who identify as non-Hispanic White(17).

Income was an important predictor of healthy dietary intake in youth with diabetes. In those with T1DM, income and parental education were associated with fruit and calcium intake. In those with T2DM, income was associated with sugar sweetened beverage and vegetable intake(12). This is especially important since socioeconomics may be associated with T1DM and T2DM, income and access will determine amount, quality, and type of food a household can buy, and education will play a role in nutrition-related knowledge and behaviors as well as health literacy.

2.1.9 Physical Activity and Sedentary Behaviors among Children, Youth and Young Adults with Diabetes

Little is known about physical activity and sedentary behaviors in youth with diabetes. There has been evidence showing benefits of physical activity in adult populations with diabetes, especially among those with T2DM. Physical activity has been associated with improved clinical outcomes including lipid levels(10, 173), endothelial functions(10), mortality(10, 174), insulin sensitivity(10, 173), body mass(173), and cardiovascular disease(10, 174). In those with T1DM, aerobic exercise may improve glycemic control(173, 175). Among adults with T2DM, physical activity was associated with improvements in blood pressure(10), beta cell function(10), glycemic control(10), and fewer episodes of hyperglycemia(176).

Similar benefits have been shown in youth and young adults(173). Among youth in Europe, increased time spent on physical activity was associated with decreases in several metabolic risk factors including insulin and glucose levels, systolic and diastolic blood pressure, and triglycerides(177). Time spent watching TV was associated with adiposity and insulin levels, but was not correlated with physical activity(177). Similarly, engaging in more time of physical activity is associated with lower A1C among youth with T1DM compared to those who exercised less(9).

2.1.9.1 Physical Activity and Sedentary Behaviors in the SEARCH for Diabetes in Youth Cohort

As in adults, adherence to physical activity and electronic media use recommendations is low in the SEARCH case control study, conducted in South Carolina and Colorado. On average, females had lower odds of vigorous physical activity, but higher

odds of compliance to electronic media standards compared to males. Those with T2DM had much lower odds of meeting the moderate to vigorous physical activity standards than those with T1DM and controls without diabetes. Among participants with T1DM or no diabetes, those participants who were obese reported participating in less vigorous physical activity and using more electronic media than those who were not obese(19).

More time spent watching television was associated with poorer diabetes-related outcomes. Youth and young adults who reported spending more time watching television had significantly greater increases in HbA1c over time greater compared to those who watched less television, especially among those with T2DM(18). Time spent watching television was also associated with significantly greater increases in serum lipid levels in those with T1DM(18).

2.2. Food Insecurity

2.2.1 Overview

The US Department of Agriculture (USDA) defines a household as experiencing food insecurity if "access to adequate food is limited by a lack of money and other resources." In 2016, there were 15.6 million households in the US that experienced food insecurity. Of these, 6.3 million children were living in households that reported food insecurity(31).

Children are often thought to be protected against the effects of food insecurity. Yet, in 2016, there were 6.5 million children living in households where caregivers reported that food insecurity was experienced by children as well as adults. There were 703,000 children who lived in households where caregivers reported that food shortages

were so severe that children were hungry, skipped a meal, or did not eat for a whole day because there was not enough money for food(31).

2.2.2 Food Insecurity and Health Outcomes

Food security is associated with changes in quantity and quality of available food periods of food availability and unpredictable periods of food shortage(48). This experience, in turn, is associated with stress, potentially leading to poorer nutrition and a reliance on hunger satiating, high calorie, low-nutrient density foods(48). However, the effects of food security extend beyond nutrition. In adults, food insecurity is associated with lower scores on physical and mental health exams(178), poorer general and mental health outcomes(178-181), mood and anxiety disorders(180-182), arthritis(182), migraines(182), and increased prevalence of cardiovascular risk factors(183-187) including high blood pressure(183, 186) and cholesterol(186-188).

2.2.2.1 Food Insecurity and Health Outcomes among Children, Youth and Young Adults

The association between food insecurity and poor outcomes for the health and wellbeing of children are likely to have negative effects that will persist throughout their lifetime(189). Behavioral, emotional, and academic problems were more common in children and adolescents living in households that report experiencing food insecurity or insufficiency(189). These include absenteeism(190, 191), tardiness(191) and suspension(192), chronic illness(192), difficulty focusing attention(191), internalizing and externalizing behaviors(192, 193), poorer academic performance(190, 193, 194) including repeating a grade(190), poorer social skills(190, 194), and poorer mental health(195) including anxiety(193), depressive disorder(196), and suicidal ideation and attempts(196).

Perhaps more troubling, the effects of food insecurity are already evident in the first few years of life. Studies have examined the association between toddlers and poor health outcomes and found, consistent with adults(56, 181), that even marginal food security can have detrimental effects on young children(180). Toddlers living in a household experiencing food insecurity have increased odds of hospitalization since birth(180, 197), poorer general health(180, 197-199), developmental issues(180, 200), physical functioning(199), and iron deficiency(198, 201) which affects attention and cognitive ability(202).

The Supplemental Nutrition Assistance Program (SNAP) is currently the largest, most accessible tool available in the United States to reduce food insecurity(203-205). However, there are strong selection effects into SNAP: many people who are eligible choose not to participate(204, 205) and, quite often, those who do participate remain food insecure(29, 204, 205). Despite this, SNAP is seen as largely successful at reducing food insecurity(203-208) and, in turn, reducing a wide range of negative health outcomes(203-205, 209, 210). Participation in food assistance is associated with better cardiometabolic profiles in children and adolescents(211), less often birthing babies of low-birthweight among pregnant women(212), better self-reported health, fewer sick days and lower healthcare utilization among adults(213), and increased medication adherence(214) and fewer hospitalizations and emergency department visits(215) among older adults.

2.2.3 Potential Risk Factors for Food Insecurity

Food insecurity is associated with poverty, but poverty can not necessarily explain food insecurity. Not all households with a low income, including those below the federal poverty line, experience food insecurity. Similarly, not all households experiencing food

insecurity are living below the federal poverty line(216-218). In 2016, 38.3% of US households with income below the poverty line were food secure. As expected, the prevalence of food insecurity decreased as income to poverty ratio increased. In 2016, 5.6% of US households with an income above 185% of the federal poverty line reported being food insecure(31). Regardless of income, households experiencing food insecurity have similar coping strategies, responses, and consequences(216).

Unexpected financial changes in the household, or economic shocks, are potential contributors to the association with food insecurity. If a household faces some financial hardship, i.e., a household member goes to jail, becomes disabled, or cannot make ends meet for some other reason, they may experience food insecurity without having a household income that is below the federal poverty line. Essentially due to expenditures that are higher than their expected income(217).

2.2.4 Food Insecurity and Nutrition

Living in households experiencing food insecurity causes changes in diets due to financial constraints. Households experiencing very low food security often report skipping meals and cutting meal sizes (97%), going hungry (68%), and losing weight (44%)(31). The prevalence of adults, especially women, meeting nutrient requirements and mean nutrient intake are much lower in food insecure households compared to food secure households(34, 35, 43).

The meal composition among members of food insecure households is different from those not experiencing food insecurity. More specifically, households experiencing food insecurity reported reducing meat and alternatives(32, 33, 35, 38, 179), milk products(32-34), and fruits and vegetables(32-38). They also reported increasing energy

density(32, 38, 39) and energy derived from carbohydrates(32, 39). Many of these dietary changes affect the whole household, but women seem to experience more severe meal changes. In some cases, these meal changes are so severe that they are at risk for nutrient deficiencies(43).

In a 1999-2002 national sample of US adults, the average daily caloric intake increased as severity of food insecurity increased in women (1,780 kcal/day in secure, 1,822 kcal/day mildly insecure, 1,876 kcal/day severely insecure), but had a u-shaped relationship in men (2,549 kcal/day in secure, 2.759 kcal/day mildly insecure, 2.543 kcal/day severely insecure). These differences were not statistically significant in either gender(39).

2.2.4.1 Food Insecurity and Nutrition among Children, Youth and Young Adults

There is some evidence that children in food insecure households experience some differences in meal content. These do not translate into statistically significant differences in nutrient adequacy, particularly among young children(32, 34, 219, 220). There has been some evidence that poverty may be an effective predictor of nutritional outcomes in pre-school aged children, but not among older children(220). However, among low income fourth and fifth graders in California, higher childhood food insecurity score, which measures awareness of food insecurity in children(221), is associated with poorer diet quality including higher total energy, fat, sugar, fiber, and lower total vegetables(222).

2.2.5 Food Insecurity and Physical Activity

Few studies have examined the relationship between food security and physical activity(223). In the US, few adults engage in enough physical activity, as measured by accelerometer(224). Among adults who met the physical activity recommendations, 6.2%

lived in food secure households and 5.9% lived in food insecure households. Food insecurity was a statistically significant predictor for general adherence (OR: 0.72, 95% CI: 0.55-0.96) and moderate to vigorous activity for ten minutes or more(223).

Similar findings were reported among Canadians(37). Individuals living in households experiencing food insecurity were more commonly classified as physically inactive compared to those households that were not(37). In contrast, Covello et al. (2017) did not find a statistically significant association between food security and physical activity. However, these findings were based on a small sample (n=113) of low-resource women in Illinois who may not be sufficiently representative of the larger population(225).

2.2.5.1 Food Insecurity and Physical Activity among Children, Youth and Young Adults

Few children in the US engage in enough physical activity to meet recommendations. In a US national sample, 31.5% of children meeting the physical activity recommendations lived in food secure households and 29.9% in food insecure households. While food insecurity was not a statistically significant predictor of adherence to physical activity recommendations, it was statistically significant for time spent engaging in moderate to vigorous physical activity(223).

There has been limited research examining the relationship between food insecurity and physical activity in children. Gunter et al. (2017) reported that facilitating physical activity, particularly in organized sports, among children was significantly more common among families in food secure households compared to those experiencing food insecurity(226). Similarly, teenage girls living in food secure households report engaging in sedentary activities less often than girls in food insecure households(227). It may be that families experiencing food insecurity may lack time or resources for children and

adolescents to engage in similar levels of physical activity as those in food secure households.

2.3 Food Insecurity and Diabetes

2.3.1 Overview

Diabetes care and management is demanding both physically and mentally. There is also a substantial financial burden associated with diabetes. This additional cost may cause increased strain on a household's resources(52, 228). Individuals with an already strained budget may need to balance the decision between high quality food, feeding family members, medications, and other necessities such as rent(41, 52). Further compounding this issue, individuals living with diabetes, especially with complications, often have substantially lower income compared to individuals without diabetes(229).

2.3.2 Epidemiology of Food Insecurity and Diabetes

Among adults living in households experiencing food insecurity, the prevalence of diabetes is higher than those living in food secure households. This has been shown in a variety of contexts in the US(39, 45, 183, 230, 231) and Canada(37, 45, 52).

In the US, diabetes is associated with food insecurity. Between 1999 and 2008, 12% of US adults 20 years and older with T1DM or T2DM were experiencing food insecurity and food insecurity was more common among those with poor glycemic control(231). Between 1999 and 2002, living in households experiencing severe food insecurity was associated with increased odds of diabetes (OR: 2.2, 95% CI: 1.1-4.0) compared to living in food secure households(39). This was confirmed in subsequent analyses of the same nationally representative US sample. In a nationally representative sample of US adults 18-65 years old, the prevalence of both self-reported (RR: 1.52; 95% CI: 1.04-2.25) and

clinical (RR: 2.42; 95% CI: 1.44-4.08) diabetes was higher among people living in households experiencing severe food insecurity compared to those living in households with low, mild, or no food insecurity(183).

In Canada, food insecurity is more common among populations with diabetes. The prevalence of food insecurity was higher among individuals 12 years and older with diabetes (9.3%) compared to those without diabetes (6.8%)(37). Similarly, 21.9% of families in Nova Scotia with a child who has diabetes reported that they were experiencing food insecurity, significantly higher than the estimate general population of Nova Scotia (14.6%) and, more generally, across Canada (9.2%)(52). In Canada, physician visits and hospitalizations are covered by the Canadian government(37, 45, 232), but prescriptions and medical supplies are not(52). Since the US has yet to adopt universal healthcare, this is an especially salient point.

2.3.3 Risk Factors Related to Experiencing Food Insecurity in Populations with Diabetes

There are several socioeconomic correlates of food insecurity(31) and these are similar for individuals with diabetes. Food insecurity was significantly associated with lower education(46, 231, 233), lower income (231, 233, 234), currently smoking(37, 233, 234), not being employed(233), not having insurance(231), and race and ethnicity(46, 231). Perceiving unmet healthcare needs (OR: 2.71, 95% CI: 1.74-4.23) is associated with increased odds of food insecurity in a national sample of Canadians with diabetes. This is especially interesting given that Canada has government-sponsored healthcare(37).

Among households where a child has diabetes, households with lower income, lower parental education, single income, single parent, and renting rather than owning the home were associated with experiencing food insecurity(52). Caregivers in these

households often reported worrying food would run out with no money for more (80%) and that they could not afford balanced meals for their family (65%)(52).

Interventions including diabetes self-management may improve gaps in health outcomes attributed to food insecurity. Lyles et al. (2013) found that individuals in food insecure households reported significantly higher HbA1c, lower self-efficacy, and lower fruit and vegetable intake than those in food secure households. After the intervention, which improved diabetes self-management education in clinics, these differences were much smaller and no longer statistically significant. The intervention showed greater improvements in those living in households experiencing food insecurity and substantially improved equity(233).

2.3.4 Health Outcomes Related to Experiencing Food Insecurity in Populations with Diabetes

People with diabetes who are experiencing food insecurity may have more difficulty managing their diabetes(230). In adults with diabetes, food insecurity is associated with poor glycemic control(231, 233, 234), increased number of contacts with physicians(46, 230), and frequent hypoglycemic events(234). In low-income populations with T2DM, food insecurity was also associated with lower self-efficacy(57, 233), poorer glucose monitoring practices(57), and increased hypoglycemic visits to the emergency department(57).

Often those with diabetes who are food insecure experience worsening glycemic control they attribute to not being able to afford adequate food(228, 235, 236) or medicine(44, 46, 57). This is substantiated by increases in hypoglycemia-related hospitalizations at the end of the month in low-income populations(237). These trends were

not seen among hospitalizations of those with higher income. Given the timing, these hospitalizations are most likely due to the cyclical nature of benefits and income being received, as well as bills and rent being due(237).

Studies examining food insecurity in youth and young adults are limited. In Canada, average HbA1c was lower among children with diabetes from food secure households (8.96% ± 1.50%) compared to food insecure households (9.50% ± 2.13%) and children from households that are food insecure were more often hospitalized(52).

In the SEARCH for Diabetes in Youth Study, 19.9% of youth and young adults with T1DM reported food insecurity. This is notably higher than the prevalence of food insecurity in the US (14.0%). It is also higher than the state-specific estimates for South Carolina (13.9%) and Washington (13.7%), where the two centers who participated in the pilot were located. Food insecurity in this sample was associated with increased odds of high risk glycemic control (OR: 2.85, 95% CI: 1.31-6.18)(116).

2.3.5 The Role of Nutrition in Food Insecurity and Diabetes

Healthy lifestyle choices are essential for people with diabetes for effective glucose control their glucose and reduce the risk for complications. Access to high quality food is an especially important component of nutrition management(7) and lack thereof can have severe consequence. As a result, food insecurity is especially problematic for people with diabetes. In addition to difficulties resulting from navigating diabetes management, limited access to food further complicates the decision-making process. Among adults with diabetes experiencing food insecurity, three main themes were identified as challenges to diabetes self-management: barriers to accessing and preparing appropriate food due to prohibitive cost or housing environments, social isolation, and demonstrating resilience

after an economic event left them temporarily food insecure(238). Similarly, in adults with T2DM, those who had poor glycemic control often reported difficulty following a diabetic diet, emotional distress related to diabetes, and self-efficacy were important domains expresses that were significantly associated with glycemic control(234).

Strategies(48) typically used by households experiencing food insecurity may not be available to people with diabetes and, in some cases, have detrimental effects. For example, households often report reducing the size or skipping meals, including going hungry, as a result of money(29). However, there is some evidence to suggest that increased meal frequency is associated with better metabolic outcomes in populations with T2DM(239, 240) and, in a similar SEARCH cohort, with T1DM(241). Importantly, Li et al. (2018) demonstrated that increasing meal frequency over time is associated with greater increases in HbA1C(241), highlighting meal frequency as an important aspect of good nutrition.

In populations who have diabetes, food insecurity is associated with dietary changes that may affect quality, including eating less fruits and vegetables or purchasing cheaper food. Comparing food secure and insecure Hispanic adults in Boston, food insecurity was associated with eating fewer plant based foods and lower dietary quality, more generally(242). Similarly, among adults with diabetes in Missouri, the average number of daily servings of fruits and vegetables were significantly lower among those who report experiencing food insecurity. However, after interventions aimed at improving diabetes self-management, these differences were no longer statistically significant(233). Canadians with diabetes living in food insecure households had decreased odds of eating

five or more fruits and vegetables per day (OR: 0.54, 95% CI: 0.33-0.81) compared to individuals living in food secure households(37).

In families with a child who has diabetes, almost half of caregivers reported buying cheaper food so that they could purchase diabetes-related supplies and half required another family member to eat less so that there was sufficient food for the child with diabetes(52).

2.3.6 The Role of Physical Activity in Food Insecurity and Diabetes

The effect of physical activity in the context of food insecurity and diabetes is relatively unknown. Considering the beneficial impact that physical activity may have on diabetes, it is exceptionally important to get all people with diabetes engaged in physical activity. Despite this, the prevalence of physical activity is low in the general population and even lower among populations with diabetes(4). In the US, 40.8% of adults with diabetes engaged in 10 minutes or less of any type of moderate or vigorous physical activity per week(4).

Participation in physical activity requires increasing the nutritional and medication needs and can be detrimental in households already facing financial constraints. Additionally, physical activity requires a substantial amount of knowledge, time, a safe space, and may be quite costly. Gucciardi et al. (2009) found that Canadians with diabetes living in food insecure households had higher odds of being physically inactive (OR: 1.54, 95% CI: 1.10-2.17) compared to individuals living in food secure households(37).

Childhood food insecurity is associated with spending less time engaging in physical activity(222). The child food insecurity score assesses awareness of food insecurity in children(221). Among low income fourth and fifth graders in California,

increasing child food security score was associated with feeling too tired to engage in physical activity (OR: 1.7, 95% CI: 1.4-2.0), children feeling that their weight was making physical activity difficult (OR: 2.0, 95% CI: 1.7-2.3), and children feeling that they did not enjoy physical activity (OR: 0.78, 95% CI: 0.70-0.86)(222). Adolescents with T2DM and their caregivers suggest that there are systemic barriers, such as community violence, that prohibit physical activity(243).

2.3.7 Gaps in Knowledge

There have been substantial efforts to understand both diabetes and food insecurity, individually, but research regarding the relationship between food insecurity and diabetes is limited, especially among children. There have been a handful of studies(45) to suggest that food insecurity and diabetes are associated, but most of these have focused on adults, do not sufficiently address T1DM (i.e., study populations are either combined due to insufficient sample of T1DM or are exclusively T2DM), and analyses are quite limited.

Diet and exercise are essential for diabetes management and have been shown to lead to beneficial outcomes(3, 6-10). Yet little is known about healthy lifestyle behaviors in people with diabetes who are experiencing food insecurity. There have been substantial efforts to better understand nutritional intake in the context of food insecurity(34, 36, 222, 242) and, separately, diabetes(11-16, 171, 244, 245). Physical activity is largely understudied in youth, especially in the context of food insecurity(223).

Generally, children are shielded from the experience of food insecurity(31). However, in households where there is increased budgetary strain due to a child with diabetes, food insecurity may be more likely to affect children. Coping mechanisms that food insecure households normally employ to avoid hunger may be problematic and not

necessarily feasible(27, 45, 47, 52). Dietary changes, such as increased reliance on carbohydrates(32, 39), and prolonging time between medications(40, 44, 46, 56, 57) may have detrimental effects in a child with diabetes. These types of coping mechanisms may make it less likely for youth and young adults with diabetes to participate in physical activity, especially since it may become less safe. Therefore, it is essential that we better understand food insecurity in youth and young adults with diabetes.

2.3.8 Conceptual Framework

Thus far, the general epidemiology has been presented for food insecurity, diabetes, and diabetes management techniques, including measures of prevalence and incidence as well as risk factors and related health outcomes. However, the context in which these experiences occur has not been yet been addressed. The framework presented here is adapted from the Social Ecological Model, which recognizes that individuals and their decision-making processes and behaviors are a function of larger social systems in which they are embedded. It is the cumulative effects resulting from various interactions between and within each level will have positive or negative effects that ultimately effect health outcomes(246, 247).

There are four hierarchical levels of the proposed framework: societal, community, interpersonal, and individual (Figure 2.1). Chronic disease, especially diabetes and related outcomes, are often attributed to individual level behaviors such as making poor dietary choices or not engaging in sufficient physical activity. However, this type of thinking ignores contextual factors that will influence health and health-related behaviors.

Food insecurity and diabetes, both T1DM and T2DM, are intrinsically linked. Food insecure populations tend to have lower quality diets(34, 42, 201, 220, 248, 249), since

these are often less expensive(38, 250). However, for someone with T1DM or T2DM, there is increased pressure on food budgets due to dietary restrictions and competing costs such as medication, clinician visits, and other household needs(37, 40, 41, 44, 45, 238). While participation in physical activity is beneficial for people with diabetes, it is costly in terms of additional food consumption, associated increases in medication requirements, and the time and money often required(7, 9, 169, 170, 173).

Nutrition and medical management are necessary to prevent poorer diabetes-related outcomes(3, 7, 8, 49, 87-90). As diabetes severity worsens, there will be less money for food and other household needs, further proliferating the cycle.

However, this does not address the larger context in which this occurs. Interpersonal factors are smaller scale direct interactions between people(251) that might enable people avoid or cope with both household food insecurity and diabetes. Social support(47, 49, 190, 243, 252, 253), familial assets or stressors(49, 181, 192, 217, 254-258), academic achievement and peer perceptions and attitudes(49, 190-192, 194, 259-262), household assets and resources(31, 49, 72, 115, 120, 122, 204, 216-218, 220), family history of illness(56, 107-109, 181, 192, 217, 254), and maternal behaviors(48, 124, 139, 147-150, 182, 183, 253, 254, 263), are also closely tied to both food insecurity and diabetes management.

Community level units include neighborhoods, cultural communities, employment and school communities, interest groups, and religious organizations. These communities may offer assets and resources that impact food insecurity and diabetes management. For example, neighborhood resources and assets such grocery stores, safety and walkability, transportation options, and nearby employment opportunities. The availability of nearby

employment opportunities offering a livable wage reducing time spent commuting or working additional jobs, reasonably priced transportation and healthy food availability, and the ability to exercise without the fear of violence will profoundly impact the ability to afford healthy meals and engage in physical activity opportunities.

Yet, the success of individuals and their communities is often a result of societal beliefs, attitudes, and norms. In the US, there has been a systematic oppression by race, ethnicity, and socioeconomic status that has proliferated throughout history. These range from federal and state policies to societal perception. Historically, federal policies like Redlining and the GI Bill influenced homeownership, the primary way for Americans to begin to accumulate wealth. These policies systematically incentivize homeownership among non-Hispanic White men while preventing anyone of color from buying a house of equivalent value in a neighborhood of equivalent quality(264).

These legacies of these policies have lingered on, disadvantaging specific groups within the population and providing fewer opportunities to obtain a quality education, less traditional means to gain assets and wealth, and fewer resources in these communities. For example, there are often socioeconomic and demographic disparities in food pricing and food quality. More specifically, food is more expensive and poorer quality foods, including increased access to fast foods, in low-income or predominantly African American or Black and Hispanic neighborhoods(265-268).

Although it is difficult to disentangle, the effects of race and ethnicity and socioeconomic status are difficult to disentangle and are often cumulative(269, 270). There is little evidence to suggest that there are genetic components to these relationships, but rather that they operate through other pathways that are moderated by stress(269).

2.3.8.1 Proposed DAGs modeling Behavioral Outcomes

To inform this dissertation and integrate the conceptual framework outlined, two DAGs are proposed. Figure 2.2 models the relationship between food security and diet, which is the outcome in RQ1. Figure 2.3 models the relationship between food security and electronic media use, which is the outcome in RQ2.

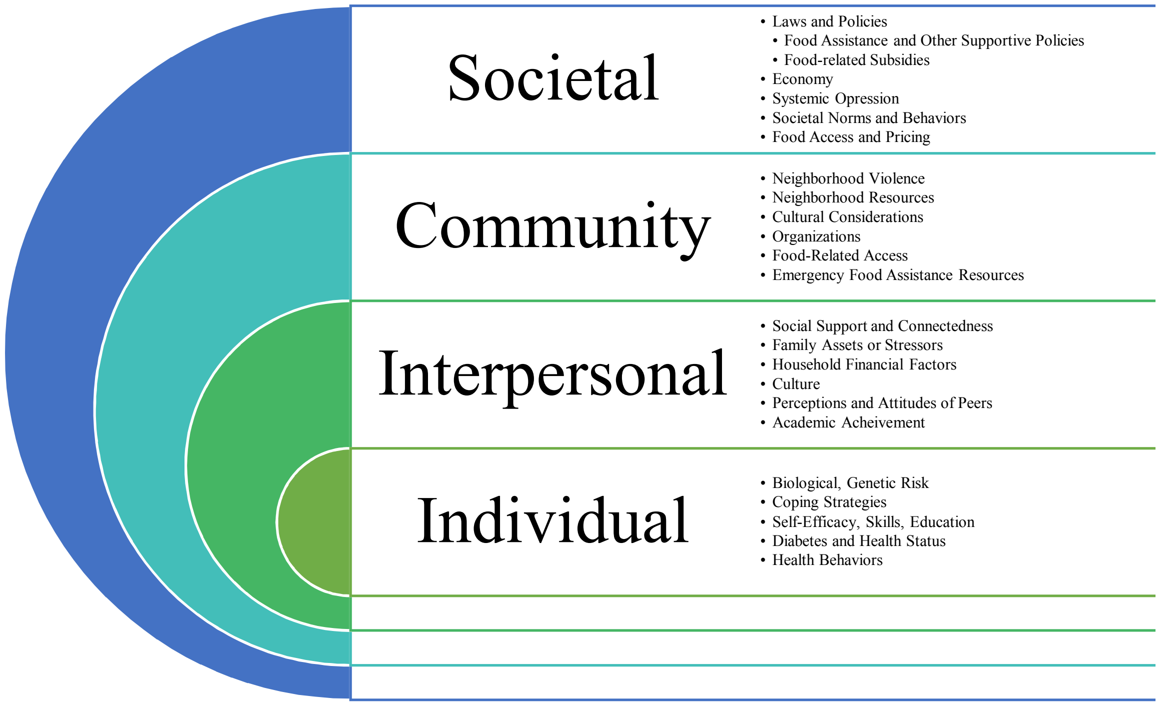

Figure 2.1 Adaptation of the Social Ecological framework to reflect the relationship between food security and diabetes

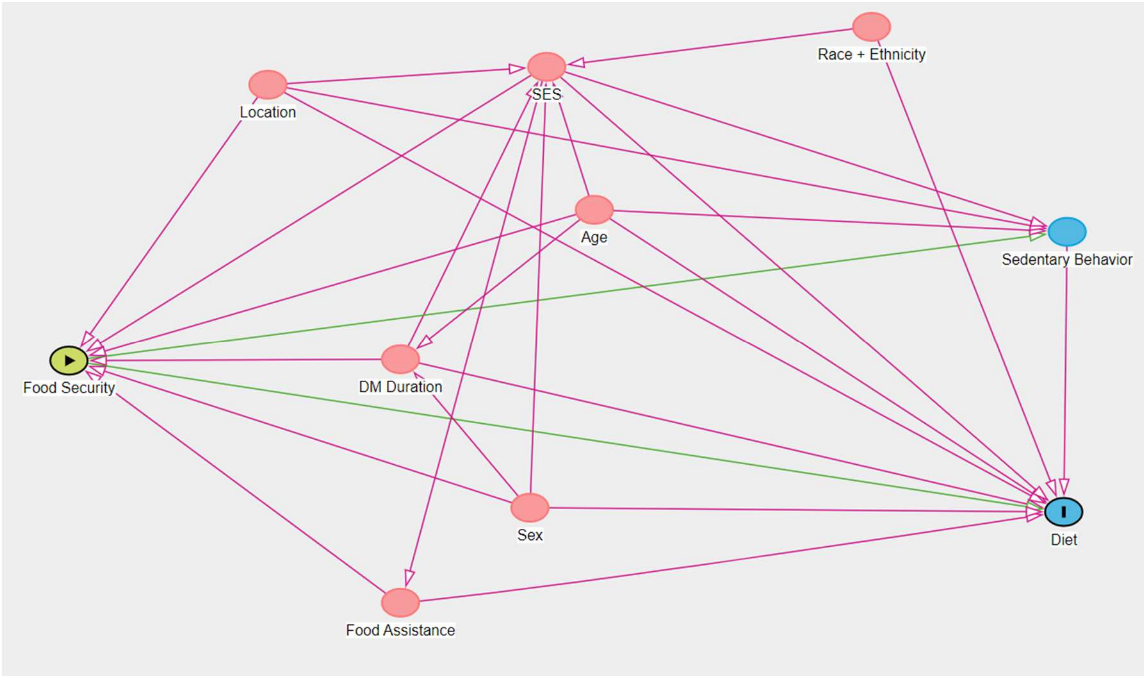

Figure 2.2 Proposed DAG modeling the relationship between food security and dietary outcomes

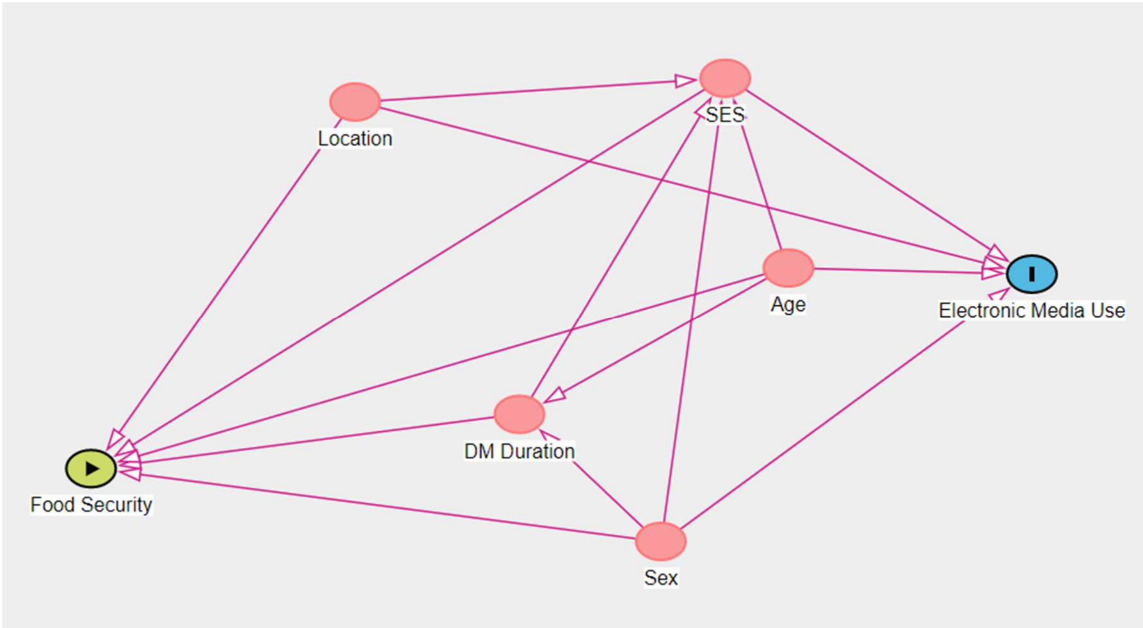

Figure 2.3 Proposed DAG modeling the relationship between food security and outcomes related to electronic media engagement

CHAPTER 3: METHODS

3.1 Specific Aims and Research Questions

The purpose of SA1 is to describe the prevalence of food insecurity in households in a sample of youth and young adults (YYA) with type 1 and type 2 diabetes. SA1 includes the following two research questions (RQ):

1. Is the prevalence of household food insecurity higher in households with youth and young adults with type 2 diabetes compared to those with type 1 diabetes?
2. Is the prevalence of household food insecurity higher in households with youth compared to young adults with diabetes, stratified by diabetes type?

The purpose of SA2 is to evaluate the association between food insecurity and behavioral outcomes, specifically dietary quality and electronic media engagement. SA2 includes the following two research questions (RQ):

1. Do youth and young adults with diabetes from households with food insecurity have poorer diet quality?
2. Do youth and young adults with diabetes from households with food insecurity spend more time engaging in engaging with electronic media, specifically television watching and leisure time computer use?

3.2 Description of the Data

3.2.1 The SEARCH for Diabetes in Youth Cohort

SEARCH for Diabetes in Youth is a multicenter study that aims to better characterize the epidemiology of diabetes in youth and adolescents in the US(64, 71, 93, 98, 113, 271-273). SEARCH began in 2000 and included six centers: Ohio (Cincinnati), Colorado (Denver), Washington (Seattle), South Carolina (Columbia, South Carolina and Chapel Hill, North Carolina), Hawaii (Honolulu), and California (Pasadena). Of these, four centers, Ohio, Colorado, Washington, and South Carolina, identified diabetes cases for inclusion from a geographically defined populations, and two centers, Hawaii and California, identified diabetes cases that were members of participating health plans. In SEARCH3, recruitment continued at five of these study: the Carolinas, Ohio, Colorado, California, and Washington. Newly diagnosed cases were ascertained through active surveillance networks developed by each center. However, the data for this dissertation are part of an ancillary pilot nested in SEARCH 3 at two of the centers, South Carolina and Washington, collecting cross-sectional data regarding food security.

The surveillance networks included pediatric and adult endocrinologists, existing pediatric diabetes databases, hospitals, community health centers, clinical and administrative data systems, electronic medical records, health plans, and other health care providers. Cases were considered eligible if their diagnosis occurred before 20 years of age, was confirmed by a referring physician or in medical records, and were members of the population under surveillance. Those in the military on active-duty, institutionalized, had diabetes as a secondary condition, or were women with gestational diabetes were not considered eligible.

To date, four SEARCH phases have been completed.. These phases have varied somewhat in design, although all had an ongoing surveillance component that included ascertainment of incident cases. SEARCH 1 (2000-2005) assessed prevalence by including cases diagnosed on or before December 31, 2001 and assessed incidence starting in 2002 through 2005. In addition to continued ascertaining incident cases between 2006-2010, SEARCH 2 also included three follow up visits for incident cases who had participated in SEARCH 1 at 12, 24, and 60 months. SEARCH 3 built further on SEARCH 2. SEARCH 3 continued ascertainment of incident cases from 2010 until 2015. In addition, SEARCH 3 selected members from previous SEARCH participants, whose diabetes duration was five or more years, to complete an additional cohort visit. Henceforth, these two components will be referred to as the registry and cohort. These two components are comprised of two mutually exclusive populations: those who were recently diagnosed (i.e., registry) and those who had diagnosed diabetes for five or more years (i.e., cohort).

3.2.2 Data Collection

SEARCH includes three main sources of data including the Medical Record (MR), the Initial Participant Survey (IPS) and the In-Person Visit (IPV). Table 3.1 outlines the SEARCH 3 data collection process. Newly diagnosed cases are ascertained as part of the registry component. After an incident case is identified within the surveillance network, a medical record review was conducted by SEARCH. In addition to basic contact and demographic information, the abstracted MR also includes relevant diabetes diagnosis information.

Potential participants were first mailed an IPS to collect basic information to confirm eligibility. These questionnaires include questions related to age, diabetes type,

racial and ethnic identity, and contact information, among others. This can be self-administered at home, but can also be completed over the phone or at the time of the in-person visit. Materials are available in both English and Spanish.

Following the IPS, participants were invited to an IPV where physical examinations, laboratory work, and additional questionnaires are administered. In previous iterations of SEARCH, all participants who completed the IPS were invited to participate in the IPV. To facilitate participation, $80.00 in gift card or cash was provided to participants.

The IPS is similar for both registry and cohort, but the IPV is much more intensive for cohort members. Cohort members were eligible for the IPV if the duration of diabetes was determined to be 5 years or longer and additional eligibility criteria for the SEARCH 3 cohort, a subset of the participants diagnosed with T1DM who identify as non-Hispanic White (50%) and all other participants with T1DM or T2DM. A general summary of participants and data collected in the IPS and IPV can be seen in Table 3.1. Surveillance efforts also included medical and mortality records, but these are not within the focus of this dissertation.

3.2.3 SEARCH Food Security Ancillary Pilot Study

Two centers, Washington and South Carolina, collected additional information as part of a pilot study on food security nested within the larger SEARCH 3 study. In tandem with existing SEARCH protocols, these sites collected additional information during the IPV including household food security, federal program assistance participation, economic status, and a child food security questionnaire. The IRB protocol for the Food Security

Pilot Study has been approved by both the University of South Carolina and Seattle's Children's Hospital.

The Food Security Ancillary Pilot Study was conducted between November 2013 and June 2015. During this time, data were collected from 373 participants including 270 (T1DM: 225, T2DM: 45) cohort participants and 103 (T1DM: 65, T2DM: 38) registry participants (Table 3.2). Due to differences in recruitment and inclusion criteria, the distributions of diabetes type differ between the registry and cohort. Both Registry and Cohort SEARCH data are used in SA1. However, only the Cohort participants provided responses to dietary intake and electronic media use questionnaires. These are the outcomes analyzed in SA2 RQ1 and RQ2.

3.3 Key Variables

3.3.i Food Security

Food security was assessed for both registry and cohort participants using the USDA's Household Food Security Status Module (HFSSM) in SEARCH(31, 274). The HFSSM has been shown to have adequate reliability(275) and validity(276).

For participants younger than 18 years old, their caregivers were asked to complete the survey since they are a knowledgeable proxy. The HFSSM assesses an adult's perceived food security in households over the past year using an 18-item questionnaire assessing household, adult, and child level coping strategies and emotional responses to not having enough food. The number of applicable items differ whether there are children in the household (18-items) or not (10-items).

To allow for comparisons between households with (18-item) and without (10-item) children, the raw food security score is adjusted or otherwise classified as per the USDA guidance outlined in Table 3.3.

Continuous measures that describe food security in these analyses include the number of affirmations and the standardized score. The number of affirmations is the raw food security score, calculated by summing all affirmative responses. From this, the standardized food security score is calculated by referencing the number of affirmative responses, as appropriate for the household (i.e., whether there are children). The standardized food security score reflects the USDA Scale Values estimated in the 1998 Current Population Survey(274).

Food security is also classified into categories of food security status (Table 3.3). Food secure households include both those who are fully food secure, with no affirmed items, and those who are marginally food secure, those that affirm one or two items. Food insecure households, defined as a score of three or higher, include both those experiencing low food security and those experiencing very low food security, defined as 8 or more affirmations in households with children and 6 or more in households without(274, 277).

Food security is the primary exposure in all etiologic analyses and is explored in all aims of this dissertation, as a continuous and categorical classification. For the purposes of this dissertation, analyses primarily rely on standardized food security score and the broader food security categories (i.e., food secure and food insecure) as predictors in the models.

3.3.2 Diabetes

Cases were identified through extensive networks of clinics and health care providers. Diabetes type and related information are initially ascertained via self-report. However, diabetes type, duration, and other diagnosis-related information are confirmed by a physician or health care provider through the abstracted electronic medical record. This is discussed in further detail elsewhere(113, 271, 273).

3.3.3 Dietary Intake

A modified version of the Block Kid's Food Questionnaire was administered to participants who were at least ten years old(17, 172). The SEARCH food frequency questionnaires (FFQ) is administered in generally the same format, however the content has been adapted to better capture the ethnic, cultural, and regional differences in the diets of SEARCH populations. Participants are asked to review a list of about 85 items and affirm whether they consumed them in the preceding week. If an item was affirmed, they were asked to describe the average portion and number of days in the week that the food item was consumed(17, 172, 278). Aside from questions about particular foods, additional questions regarding dietary supplements, low-fat products, eating out, and whether the report of the past week is reflective of a typical week's consumption(17). The SEARCH FFQ has been shown to have acceptable correlations with diet recall in a similar SEARCH population aged 10-24 years(172).

3.3.3.1 Dietary Quality

Dietary quality was measured by adherence to the Dietary Approaches to Stop Hypertension (DASH) recommendations from the National Heart, Lung, and Blood Institute. The DASH diet centers around 8 food groups: grains, vegetables, fruits, dairy,

meat including poultry, fish, and eggs, nuts and seeds including legumes, fats and oils, and sweets(14, 15, 279-281). Component scores are calculated by level of adherence to dietary recommendations(280) for each food group (Table 3.4), with a maximum value of 10 if the recommendations specific to that food group have been met and scored proportionally when they are not(281). To describe overall dietary quality(14, 15, 281), an overall index is derived and incorporates adherence to the recommendations of each of the food groups. Overall DASH score(281) is the combined component scores of all 8 food groups, ranging from 0-80, a higher score indicating broader adherence to recommendations.

Most dietary recommendations promote eating more healthy foods(279, 280). As a result, for most food groups, a higher component score is reflective of a higher intake(281). However, when it is recommended to limit intake of a specific food group (279, 280), specifically for meat, poultry, fish, and egg, fat and oil, and sweet, scoring is reversed(281). Two components, grain and dairy, are composites and consider measures of quality (i.e., whole grains and low-fat dairy)(279, 280). For these components, total intake and the quality component are combined, each counting equally (out of 5) when calculating the component score (out of 10)(281).

There are several levels of DASH eating guidance, based upon estimated energy requirement(281). The DASH diet provides guidance in 4 levels of energy intake (Table 3.4), 1600, 2000, 2300, and 3100 kcal per day(279-281). Each level outlines a recommended amount of each food group to be incorporated, appropriately adjusting for recommended caloric intake. Estimated energy requirements are calculated based upon age, sex, and physical activity level(281, 282).

Participants are classified as either active, low active, or sedentary based on the number of days they engage in vigorous and or moderate physical activity. Active participants participate in both vigorous and moderate physical activity five or more per week whereas participants are classified as low active if they participate in either five or more days per week and sedentary if they do neither five or more days per week.

Physical activity is assessed using two questions from the Youth Risk Behavior Surveillance System(283). Number of days engaging in vigorous physical activity is estimated based on the response to the question "On how many of the past 7 days did you exercise or participate in a physical activity for at least 20 minutes that made you sweat and breathe hard?" Number of days engaging in moderate physical activity is estimated based on the response to the question "On how many of the past 7 days did you exercise or participate in a physical activity for at least 30 minutes that did not make you sweat and breathe hard?"

3.3.4 Electronic Media Use

Electronic Media Use (E-M) is assessed as part of the physical activity questionnaire administered to participants 10 years and older(18). Electronic media use questions were adapted from the Youth Risk Behavioral Survey (YRBS) questionnaire(284). The YRBS has been shown to have adequate reliability and validity(285, 286).

Participants are asked about weekday and weekend specific television and leisure computer use. The questions are as follows: "On each (weekday/weekend), about how much time do you usually spend watching TV?", "On each (weekday/weekend), about how much time do you usually spend on the computer for fun, including playing video or

computer games? Please do not include time on the computer for school or work." Responses include: "None", "Less than 1 hour", "1 hour", "2 hours", "3 hours", "4 hours", and "5 or more hours". These responses were integrated to reflect an average week's television and computer use (Formula 3.1). For calculations including respondents who selected "Less than an hour" or "5 hours or more", 0.5 and 5 hours will be used, respectively. For participants with missing or invalid responses to average weekend use, calculations assume weekday use is representative.

Formula 3.1

$$Weekly\ Time\ Spent\ using\ Electronic\ Media = (weekday\ use * 5) + (weekend\ use * 2)$$

3.3.5 Covariates

There are many covariates that have theoretical importance in these analyses. These have been presented in the DAG in Figure 2.2 and Figure 2.3. Participant sex, age, diabetes status (i.e., type and duration), and interview site are used for adjustment in most analyses.

Age, sex, race/ethnicity, and diabetes status were all ascertained through self-report in the IPS and confirmed using the EMR. Interview site is determined as whichever site recorded the visit. Health Insurance, education, household income, number of children, and number of adults are assessed through a questionnaire filled out by either the parent (if the participant is under 18 years old) or participants (over 18 years old).

3.3.5.1 Anthropometric Measures

During the SEARCH in-person visit, the clinician measured the participant's height (in cm), weight (in kg), and waist circumference (in cm) in two places(278, 287, 288). Waist circumference was first measured in accordance with the US National Health and

Nutrition Examination Survey (NHANES) protocol at the top of the iliac crest. Another measurement was taken at the natural waist, the level of the umbilicus, halfway between the lower rib and the iliac crest, as suggested by the World Health Organization (WHO). For each measure, the clinician took two measurements to the nearest 0.1 unit. If the two measurements of height differ by more than 0.5 cm, a third measurement is taken. If the two measurements of weight differed by more than 0.3 kg, a third measurement was taken. For each of the two types of waist circumference, if the two measurements differed by more than 1.0 cm, a third measurement was taken. BMI was calculated as a function of weight and height, more specifically, kg/m2.

3.3.5.2 Socioeconomic Status

Socioeconomic status is a composite, derived from two variables: household income (see 3.3.5.2.1) and education (see 3.3.5.2.2). High socioeconomic status is defined as participants who report either an annual household income of $50,000 or higher and those who reported having a bachelor's degree or higher. Participants not meeting those criteria who provided a non-missing, valid response for either income or education information were classified as not having high socioeconomic status.

3.3.5.2.1 Household Income

The participant or, if younger than 18 years, the parent or guardian was asked "Which of these categories best describes the total income of all persons living in your household for the past 12 months?" Responses include the following: Less than $5,000, $5,000 through $11,999, $12,000 through $15,999, $16,000 through $24,999, $25,000 through $34,999, $35,000 through $49,999, $50,000 through $74,999, $75,000 through $99,999, $100,000 and greater, don't know, or prefer not to answer. Since the median

household income in the United States from 2010-14 was $53,046 (SC: $45,033; WA: $60,294)(289), $50,000 was used to categorize high versus low household income.

3.3.5.2.2 Education

For those children younger than 18 years old, their parent or guardian is asked the question about the highest degree of education that they have completed, then separately about their spouse or partner. In the young adult version, the questions ask about caregiver(s). There are 17 available responses: No schooling, nursery school to fourth grade, fifth or sixth grade, seventh or eighth grade, ninth grade, tenth grade, eleventh grade, twelfth grade without diploma, high school graduate or equivalent (i.e., GED), business or technical school, some college (<1 year), more than a year of college without degree, associate's degree (i.e., AA, AS – 2 year), bachelor's degree (i.e., BA, AB, BS – 4 year), master's degree (i.e., MA, MS, MEng, Med, MSW), professional or doctorate degree (I.e., MD, DDS, JD, PhD, EdD), or don't know.

3.3.5.3 Assistance Program Participation

Assistance Program Participation is assessed in the Household Food Security and Food Assistance Survey through the following four questions: "In the past 12 months, did you or any members of your household receive Food Stamps, known as the Supplemental Nutrition Assistance Program or SNAP?", "In the past 12 months, did you or any members of your household receive benefits from the WIC Program, that is, the Women, Infants and Children program?", "In the past 12 months, did you or any members of your household receive emergency food from a church, food pantry, or a food bank, or eat in a soup kitchen?", and "In the last 12 months, did your child unusually receive free or reduced

price lunch at school?” For all of these questions, participants could choose one of three responses: “Yes”, “No”, or “Refuse or Don’t Know”.

Participation in any food assistance program includes any participant that responds affirmatively to any of the questions about program participation. Conversely, those that provide at least one negative response and do not affirm participation in any of the identified programs are classified as not participating.

3.4 Statistical Analyses

3.4.1 Specific Aim 1 (SA1)

To address specific aim 1, prevalence estimates were calculated using simple proportions and 95% confidence intervals. Analyses for this aim included all registry and cohort participants with complete data including all diabetes types and ages. Relevant variables for Specific Aim 1 are described in more detail in Table 3.5.

First, estimating the prevalence of food insecurity (FIS), stratified by type of diabetes (Formula 3.2). Subsequent analyses also stratify by participant sex.

Formula 3.2

$$\hat{\rho}_{FIS,i} = \frac{n_{FISi}}{n_i}$$

Where, i is diabetes type (T1DM or T2DM), n_i is the total number of households of each type n_{FISi}, is the number of households experiencing food insecurity for each diabetes type, and $\hat{\rho}_{FSS,i}$ is the estimated proportion of households experiencing food insecurity for each diabetes type. The 95% confidence intervals for each proportion were calculated using the Agresti-Coull Interval Method(290)(Formula 3.3).

Formula 3.3

$$\left(\frac{\hat{\rho}_{FIS,i} + \frac{z^2 \alpha/_2}{2n_{FIS,i}} \pm z\alpha/_2 \sqrt{\frac{\hat{\rho}_{FIS,i}\left(1 - \hat{\rho}_{FIS,i}\right)}{n_{FIS,i}} + \frac{z_{\alpha}^2/_2}{4n_{FIS,i}{}^2}}}{1 + {}^{z^2 \alpha/_2}\big/_{n_{FIS,i}}}\right)$$

Then, evaluating the food security status across age groups, stratified by diabetes type and participant's sex. These are similar to those previously described principles with a simple modification to calculate the prevalence (Formula 3.4) and 95% confidence intervals (Formula 3.5) in age- and sex-specific strata.

Formula 3.4

$$\hat{\rho}_{FIS,ik} = \frac{n_{FIS,ik}}{n_{ik}}$$

Where, k is the sex and age group of interest, i.e., participants 17 years old and younger participants 18 years and older, among male or female participants and all other specifications as previously described (Formula 3.2).

Formula 3.5

$$\left(\frac{\hat{\rho}_{FIS,ik} + \frac{z^2 \alpha/_2}{2n_{FIS,ik}} \pm z\alpha/_2 \sqrt{\frac{\hat{\rho}_{FIS,ik}\left(1 - \hat{\rho}_{FIS,i}\right)}{n_{FIS,ik}} + \frac{z_{\alpha}^2/_2}{4n_{FIS,ik}{}^2}}}{1 + {}^{z^2 \alpha/_2}\big/_{n_{FIS,ik}}}\right)$$

Pearson's chi-squared test or Fisher's exact test was used to test for significance, as appropriate. The assumptions for both tests include categorical outcomes and independent strata. These are both true, by design. Another assumption of Pearson's chi-square is that cell counts are sufficiently large. Where expected cell counts are less than five, Fisher's exact test would be more appropriate.

3.4.2 Specific Aim 2 (SA2)

The behavioral outcomes relevant for SA2, specifically dietary outcomes (RQ1) and engagement with electronic media (RQ2), are only ascertained from the cohort participants who were at least 10 years old at the time of the cohort visit. As a result, the analytic sample includes only those 10 years and older who met the eligibility criteria for the cohort, including having been diagnosed at least 5 years prior, and did not provide missing or invalid responses for any of the relevant variables (Table 3.6).

As a preliminary step, descriptive statistics were used to characterize relevant variables, overall and stratified by household food security status. Means and standard deviations or frequencies and proportions were reported, as appropriate, using either Analysis of Variance (ANOVA), Pearson's chi-squared test, or Fisher's Exact to test for statistically significant differences by food security status. For all analyses, statistical significance was determined by using a 5% significance level (i.e., $\alpha=0.05$).

Continuous outcomes include adherence to DASH overall index, DASH sub-component adherence scores (i.e., grains, vegetables, fruits, dairy, meats and eggs including poultry and fish, nuts and seeds including legumes, fats and oils, and sweets), average electronic media use (i.e., television watching and leisure time computer use) daily, on weekday days, and on weekend days (Table 3.6). To increase interpretability of findings, dietary outcomes were categorized by data driven tertiles and electronic media use were categorized into high vs low use, 2 or more hours for the individual outcomes (i.e., television watching or computer use) and 4 or more hours for the overall indicator of electronic media use (Table 3.6).

To evaluate the association with food security status and continuous outcomes, generalized linear models (i.e., SAS PROC GENMOD) was used, specified with an identity link and a normal distribution as per Formula 3.6. Although somewhat relaxed compared to ordinary least squares, the basic assumptions of linear regression are necessary to be met, specifically homoscedasticity, independence, linearity, and normality. These assumptions can be tested using model residuals, making appropriate adjustments as needed.

Formula 3.6

$$g(\mu) = \mu$$

To evaluate the association with food security status and categorical outcomes, generalized linear models (i.e., SAS PROC GENMOD) was used, specified with a logit link and a binomial distribution as per Formula 3.7. For the dietary outcomes, multiple logits are used, comparing high or mid-level adherence tertiles to the low-level adherence tertiles. The basic assumptions of logistic regression include a binary outcome, independent observations, linearity between the predictors and the log odds of the outcomes, and logit models require more observations.

Formula 3.7

$$g(\mu) = \ln\left(\frac{\mu}{1 - \mu}\right)$$

Outcomes in SA2 were analyzed using several models, this includes both continuous and categorical outcomes. Initially, each of the outcomes was analyzed in crude, unadjusted models. First with food security included as a continuous predictor, i.e., standardized score (Formula 3.8), then with food security categorized as a status, i.e., food insecurity (Formula 3.9). Subsequently, analyses included full adjustment for covariates

identified each outcome-specific DAG (Figures 2.2-3). For dietary outcomes, this includes adjusting for age at visit, clinic location, any food assistance participation, high socioeconomic status, diabetes duration, diabetes type, and participant's sex. For electronic media outcomes, this includes adjusting for age at visit, sex, clinic location, high socioeconomic status, diabetes type, and participant's sex. Adjusted models have been outlined in Formula 3.10-3.11.

Formula 3.8

$$g(\mu) = \beta_0 + \beta_{FSScore} FSScore + \epsilon$$

Where, $g(\mu)$ is the appropriate link function (Figures 3.6-7), modeling the relationship to the outcome, β_0 is the intercept, $\beta_{FSScore}$ is the regression coefficient for the food security variable, and $FSScore$ is the standardized score representing the level of food security within the household.

Formula 3.9

$$g(\mu) = \beta_0 + \beta_{FSStatus} FSStatus + \epsilon$$

Similar to Formula 3.8, $g(\mu)$ is the link function, modeling the relationship to the outcome, β_0 is the intercept, $\beta_{FSStatus}$ is the regression coefficient for the food security variable, and $FSStatus$ is an indicator for the presence of food insecurity in the household, compared to food secure.

Formula 3.10

$$g(\mu) = \beta_0 + \beta_{FSScore} FSScore + \beta_{T2DM} T2DM + \sum_{i=1}^{k} \beta_i z_i + \epsilon$$

Where, β_{T2DM} is the regression coefficient for type 2 diabetes, $T2DM$ is the dichotomized variable representing a participant with type 2 diabetes compared to a participant with type 1 diabetes, and all other specifications the same as previously described (Formula 3.8). Where, k is the number of additional covariates in the model, β_i represents the additional regression coefficients for each covariate, z_i additional covariates. For dietary outcomes, this includes adjusting for participant's sex, age, diabetes duration, participation in food assistance, clinic location, and high socioeconomic status, in addition to diabetes type. For electronic media outcomes, this includes adjusting for participant's sex, age, clinic location, and high socioeconomic status, in addition to diabetes type.

Formula 3.11

$$g(\mu) = \beta_0 + \beta_{FSStatus} FSStatus + \beta_{T2DM} T2DM + \sum_{i=1}^{k} \beta_i z_i + \epsilon$$

Where, $\beta_{FSStatus}$ is the regression coefficient for the food security variable, and $FSStatus$ is an indicator for the presence of food insecurity in the household, compared to food secure, and all other specifications the same as previously described (Formula 3.10).

3.4.3 Model Fit

Model assumptions were checked prior to analysis. For linear regression, model assumptions include linearity, normality, independence, and homoscedasticity which were assessed using model residual graphs and tables. Independence is confirmed, by design. For logistic regression, the model must be linear on the logit scale (i.e., be a good fit for the data), using the Hosmer-Lemeshow Goodness of Fit test, and observations must be independent. .

There are additional concerns of endogeneity, multicollinearity, influential points, and outliers. These must be examined to ensure that the model is appropriate. Endogeneity will be examined through correlations. Multicollinearity will be evaluated using the variance inflation factor (VIF) or tolerance (VIF^{-1}), a VIF greater than 10 or a tolerance of less than 0.1 warrants further investigation. Influential points will be assessed using Cook's distance, further examining any point with a value approaching 1. Any observation that has an exceedingly large residual will be examined as a potential outlier. Observations that are potentially influential points and outliers will be thoroughly assessed in all diagnostic plots of residuals and investigated.

3.4.4 Missing Data

Methods to account for attrition have been described in the context of the larger SEARCH study as a way to maintain representativeness and generalizability. However, data used in this dissertation are part of a pilot including cross-sectional data from two sites. These data are not intended to be representative.

Participants were most often missing data on income. To accommodate this, a composite socioeconomic indicator was created from participant income and education. Participants who reported an annual household income of $50,000 or higher and those who reported having a bachelor's degree or higher were categorized as high socioeconomic status. Those who reported income or education, but did not meet those criteria were classified as low socioeconomic status.

Table 3.1. Data collected in SEARCH 3

	Registry, Eligible	Registry Data Collection	Cohort, Eligible	Cohort Data Collection
Initial Participant Mail/Phone Survey (IPS)	2010-2014	Date of birth, data of diagnosis, gender, self-reported race/ethnicity, residence in the year of diagnosis, health insurance, diabetes care, education of parents, treatment history, secondary diabetes, presentation symptomology, complications, medication, family history, contact information, reported height and weight		Completed at baseline either over the phone or through a mailed packet, contains similar information to the Registry IPS
In-Person Visit (IPV)		Physical Exam including height, weight, waist circumference, BP, acanthosis nigricans, Medical inventory of currently prescribed medications, lab specimens (i.e., fasting glucose, lipids, etc.), repository (i.e., serum, DNA, etc.)	Incident cases in the 2002-2005, 2006, and 2008 cohorts of SEARCH who were diagnosed with diabetes 5+ years prior	Collected all information collected in Registry IPV. Additionally, the cohort IPV collected: updated demographics and SES indicators, processes of care including transition, quality of care, family structure, quality of life,

			50% of non-Hispanic White participants with T1DM were eligible and 100% of all other groups with T1DM or T2DM	diabetes family interaction scale, diabetes eating problems survey, and examination of comorbities. If >10y, tanner stage parent and participant education, diet, physical activity, tobacco use, alcohol, depressive symptoms, pregnancy.

Table 3.2. Number of registry and cohort cases in SEARCH 3, by type of diabetes and site

	Overall		**Washington**		**Carolina**	
	T1DM	T2DM	T1DM	T2DM	T1DM	T2DM
Registry	65	38	46	13	19	25
Cohort	225	45	140	11	85	34

Table 3.3. Food security scores and corresponding statuses, as defined by the USDA

Food Security Status[a]	**Level of Food Security**	**Number of Affirmative Responses**		**Standardized Food Security Score**
		Households with Children	**Households without Children**	
		18-Items	*10-Items*	
Food Secure	High	0	0	0
	Marginal	1		1.0
			1	1.2
		2		1.8
			2	2.2
Food Insecure	Low	3		2.4
		4		3.0
			3	3.0
		5		3.4
			4	3.7
		6		3.9
		7		4.3
			5	4.4
	Very Low	8		4.7
			6	5.0
		9		5.1
		10		5.5
			7	5.7
		11		5.9
		12		6.3
			8	6.4

		13		6.6
		14		7.0
			9	7.2
		15		7.4
			10	7.9
		16		8.0
		17		8.7
		18		9.3

[a]Scores are calculated and classified in USDA guidance on using the Household Food Security Status Module (HFSSM)(274, 291)

Table 3.4. DASH components and scoring standards, including serving recommendations for maximum component score for 1600, 2000, 2600, and 3100 kcal diets

Component[a]		Score Range	Serving Recommendations				
			Number of Servings Recommended, by Estimated Energy Requirement[b] (in kcal per day)				Frequency
			1600	2000	2600	3100	
Grains							
	Total Grains	0-5	≥6	≥6	≥10	≥12	Daily
	High Fiber	0-5	≥50%	≥50%	≥50%	≥50%	
Vegetables		0-10	≥3	≥4	≥5	≥6	Daily
Fruits		0-10	≥4	≥4	≥5	≥6	Daily
Dairy							
	Total Dairy	0-5	≥2	≥2	≥3	≥3	Daily
	Low-Fat	0-5	≥75%	≥75%	≥75%	≥75%	
Meats, Poultry, Fish, Eggs[c]		0-10	≤2	≤2	≤2	≤3	Daily
Nuts, Seeds, Legumes		0-10	≥3	≥4	≥7	≥7	Weekly
Fats and Oils[c]		0-10	≤2	≤3	≤3	≤4	Daily
Sweets[c]		0-10	≤0	≤5	≤14	≤14	Weekly

[a]For most components, a minimum score will be assigned if participants do not report any foods containing the specified component, whereas a maximum score is assigned. In contrast, the meat, poultry, fish, and egg, fat and oil, and sweet components are reverse scored.

[b]Estimated Energy Requirement is specific to age, sex, and physical activity level.

[c]Dietary recommendations suggest limiting intake of three components: meats, poultry, fish, and eggs, fats and oils, and sweets. As a result, scoring is reversed. Dietary intake of these components that does not exceed the recommended amount will be assigned the maximum score (i.e., 10), whereas intake at or above double the recommended amount will be assigned the minimum score (i.e., 0)

Table 3.5. Relevant variables for analysis of research questions (RQs) explored in specific aim (SA) 1

	RQ	Measure	Type	Description
Outcome				
Food Security	1.1-2	Food Security Status	Categorical	Food insecure, defined as 3 or more affirmations, compared to food secure
Exposures				
Diabetes Type	1.1-2	Diabetes Type	Categorical	Type 2 or Type 1, as reference
Sex	1.1-2	Participant's Sex	Categorical	Male or Female, as reference
Age	-	Age at Visit	Continuous	Age, in years, at time of cohort visit
	1.2		Categorical	Age at visit, categorized as older, at least 18 years old, or younger, for those younger than 18 years old

Table 3.6. Relevant variables for analysis of research questions (RQs) explored in specific aim (SA) 2

	RQ	Measure	Type	Description
Outcomes				
Overall Adherence to Dietary Recommendations	2.1	Overall DASH Adherence Index Score	Continuous	Index of Overall Compliance, 0-80, sum of sub-components
	2.1	Tertiles of Overall DASH Adherence	Categorical	Adherence to overall DASH index score, by data-driven tertiles
Adherence Food Group-Specific Dietary Recommendations	2.1	DASH Sub-component Adherence Score	Continuous	Sub-Component Compliance, 0-10, (i.e., grains, vegetables, fruits, dairy, meats and eggs including poultry and fish, nuts and seeds including legumes, fats and oils, and sweets)
	2.1	Tertiles of Sub-component DASH Adherence	Categorical	Adherence to DASH sub-components, by data-driven tertiles
Daily Electronic Media Use	2.2	Electronic Media Use	Continuous	Daily average electronic media use, i.e., television and computer use, overall, on weekdays, and on weekends
	2.2	Level of Electronic Media Use	Categorical	High daily average electronic media use, i.e., over 4 hours per day, compared to low

	Daily Television Watching	2.2	Television Watching	Continuous	Daily average television use, overall, on weekdays, and on weekends
		2.2	Level of Television Use	Categorical	High daily average television watching, i.e., over 2 hours per day, compared to low
	Daily Computer Use	2.2	Computer Use	Continuous	Daily average television use, overall, on weekdays, and on weekends
		2.2	Level of Computer Use	Categorical	High daily average electronic media use, i.e., over 2 hours per day, compared to low
Exposure					
	Food Security	2.1-2	Standardized Food Security Score	Continuous	Number of affirmations to the 18-item Household Food Security Status Module, standardized
		2.1-2	Food Security Status	Categorical	Food insecure, defined as 3 or more affirmations, compared to food secure
Covariates					
	Diabetes Type	2.1-2	Diabetes Type	Categorical	Type 2 or Type 1, as reference
	Age	2.1-2	Age at Visit	Continuous	Age, in years, at time of cohort visit
	Sex	2.1-2	Participant's Sex	Categorical	Male or Female, as reference
	Diabetes Duration	2.1	Time since diabetes diagnosis	Continuous	Time, in months, since diabetes diagnosis

	Food Assistance	2.1	Participation in a food assistance in the past 12 months	Categorical	Participation in any food assistance is defined as participation in SNAP, WIC, Free or Reduced School Lunch, or receiving emergency food (e.g., from a church, food pantry, soup kitchen) in the previous 12 months.
	Clinic Site	2.1-2	Clinic location	Categorical	Participant from Washington or South Carolina, as reference
	Socioeconomic Status	2.1-2	Socioeconomic Status	Categorical	High socioeconomic status is defined as participants who report an annual household income of $50,000 or higher and those who reported having a bachelor's degree or higher.

CHAPTER 4: RESULTS

4.1 Specific Aim 1 (SA1)

There were 377 people who participated in the SEARCH for Diabetes in Youth study at the Washington and South Carolina sites. This included 103 newly diagnosed or registry participants and 274 cohort participants who were diagnosed with diabetes at least 5 years prior to the start of SEARCH 3. Those participants for whom diabetes type (n=4) or age (n=2) was unknown and those with incomplete information on food security status (n=16) were excluded from the analyses.

Characteristics of the analytic sample are shown in Table 4.1. The average age of participants was 16.9±5.5 years old, ranging from 3.0 to 30.7 years old, and just over half of the sample is female (52.1%). The majority of participants had T1DM (78.6%; n=279) and originated from the SEARCH cohort (74.1%; n=263). Participation in at least one assistance program, including the Supplemental Nutrition Assistance Program (SNAP), the Special Supplemental Nutrition Assistance Program for Women, Infants and Children (WIC), receiving emergency food from a church, food pantry, food bank, soup kitchen, or the child received free or reduced cost lunch at school, in the previous year was common among participants (39.8%; n=141).

Most participants were food secure (78.6%, n=279) during the year prior, but 21.4% experienced food insecurity, including 7.6% who experienced very low food security.

Participants may be food secure and still experience marginal food insecurity, affirming one or two items in the household food security module. Indeed, at least 32.3% of the sample experienced some form of food insecurity (i.e., affirmed any of the food security items). On average, participants in the analytic sample affirmed 1.5 (±3.0) items, the mean standardized food security score was 1.0 (±1.7).

Comparing by diabetes type, there were statistically significant differences in age, location, participation in any food assistance program, and whether the participant was a member of the SEARCH registry or cohort (Table 4.2). Those with T2DM were, on average, older (T1DM: 16.1±5.5, T2DM: 20.0±4.7, p-value: <0.0001). A higher proportion of those with T2DM participated in a food assistance program (T1DM: 30.1%, T2DM: 76.0%, p-value: <0.0001) and visited the South Carolina clinic (T1DM: 34.1%, T2DM: 71.1%, p-value: <0.0001). In contrast, the majority of YYA with T1DM were represented in the cohort (78.5%) whereas YYA with T2DM were distributed similarly across the registry (57.9%) and cohort (42.1%) (p-value: 0.0003).

4.1.1 Food Security and Diabetes Type

Overall, 21.4% of the sample was food insecure (Table 4.1). Among those who were food secure (78.6%, n=279), 14% (n=39) were marginally food secure and reported experiencing one or two of the items assessed in the USDA's Household Food Security Survey Module (HFSSM). However, 67.6% of the overall sample (n=240) reported no experiences of food insecurity (i.e., affirmed no items in the HFSSM).

There were statistically significant differences in continuous measures of food insecurity. YYA with T2DM affirmed, on average, 2.5±3.6 items whereas YYA with T1DM affirmed 1.2±2.7 items (p-value: 0.001). The mean standardized food security score

was 0.8±1.6 among YYA with T1DM and 1.7±2.1 among those with T2DM (p-value: 0.0002).

The prevalence of food insecurity was higher among those with T2DM (36.8%; 95% CI: 26.9-48.1) than T1DM (17.2%; 95% CI: 13.2-22.1; Table 4.2), which was statistically significant (p-value: 0.0002; Table 4.1). Furthermore, the proportion of participants with T2DM (11.8%) experiencing very low food security was almost double that of T1DM (6.5%; Table 4.1). Comparing by participant sex, 20.7% (95% CI: 14.7-28.4) of males with T1DM were experiencing food insecurity compared to 13.9% (95% CI: 9.1-20.6) of females with T1DM (Table 4.2). In contrast, food insecurity was similar for both males (37.1%; 95% CI: 23.2-53.7) and females (36.6%; 95% CI: 23.6-51.9) among those with T2DM (Table 4.2).

4.1.2 Food Security and Age

There were similar trends in food insecurity regardless of age group. Overall, 21.4% of the sample was food insecure, which was similar for younger (0-17 years: 21.9%) and older (≥18 years: 20.8%) participants (data not shown).

Among YYA with T1DM, the prevalence of food insecurity was 19.0% (95% CI: 13.8-25.7) in younger participants under 18 years old and 14.4% (95% CI: 9.0-22.2) in older participants 18 years and older (Table 4.2). There were no significant differences in the number of items affirmed (0-17 years: 1.4±3.0; ≥18 years: 1.0±2.0; p-value: 0.2) or standardized score (0-17 years: 0.9±1.7; ≥18 years: 0.8±1.4; p-value: 0.5) when comparing age groups in those with T1DM (data not shown). The average age of participants with T1DM was 16.1 years old and did not differ by food security status (FS: 16.2±5.6; FIS: 15.7±4.7; p-value: 0.5; data not shown).

Among participants with T2DM, the prevalence of food insecurity was 39.3% (95% CI: 23.5-57.6) for younger participants and 35.4% (95% CI: 23.4-49.6) in older participants (Table 4.2). Again, there were no significant differences in the number of items affirmed (0-17 years: 2.8±4.1; ≥18 years: 2.3±3.4; p-value: 0.5) or standardized score (0-17 years: 1.8±2.2; ≥18 years: 1.6±2.0; p-value: 0.6) when comparing age groups in those with T2DM (Table 4.2). The average age of participants with T2DM was 20.0 years old and did not differ by food security status (FS: 20.0±4.6; FIS: 20.0±5.0; p-value: >0.9; data not shown).

Males more often reported experiencing food insecurity for most age and diabetes-specific strata. Among those with T1DM, 22.4% (95% CI: 14.7-32.4) of males under 18 years old and 18.0% (95% CI: 9.5-31.0) over 18 years old were food insecure, comparatively higher than their female counterparts (0-17 years: 15.7%, 95% CI: 9.3-25.1; ≥18 years: 11.5, 95% CI: 5.4-22.1). Similar trends were seen among younger participants with T2DM (Males: 46.2%, 95% CI: 23.2-70.9; Females: 33.3%, 95% CI: 15.0-58.5; Table 4.2). Notably, though younger males more often reported food insecurity among both those with T1DM (0-17 years: 22.4%, 95% CI: 14.7-32.4; ≥18 years: 18.0%, 95% CI: 9.5-31.0) and those with T2DM (0-17 years: 46.2%, 95% CI: 23.2-70.9; ≥18 years: 31.8%, 95% CI: 16.2-52.9), the opposite was true among females.

4.2 Specific Aim 2 (SA2)

4.2.1 Food Security and Dietary Quality

There were 274 cohort participants who were diagnosed with diabetes at least 5 years prior to the start of SEARCH 3 at the Washington and South Carolina sites. Participants were excluded if they were missing information key indicators such as dietary intake (n=35) and household food security (n=7). Participants were also excluded if they

did not provided information on covariates, including food assistance participation (n=5), socioeconomic status (i.e., no known income or education; n=6), and diabetes type (n=4) were also excluded. As a result, the final analytic sample for dietary quality included 226 cohort-only participants.

4.2.1.1 Sample Characteristics

Characteristics of the analytic sample for dietary outcomes are shown in Table 4.4. This sample was majority female (54.4%, n=123), non-Hispanic White (68.6%, n=155), lived in a household with two caregivers (61.9%, n=138), did not participate in any food assistance programs (62.8%, n=142), and had been diagnosed with T1DM (82.3%, n=186). On average, participants were 18.7±4.8 years old and have been diagnosed with diabetes for 101.5±26.4 months, which is, on average, slightly less than 8.5 years.

Most of the analytic sample was food secure (80.5%, n=182), however 19.5% of participants were living in food insecure households, defined as experiencing three or more of the items assessed in the USDA's Household Food Security Survey Module (HFSSM). Among the food secure participants, 16.5% were marginally food secure and reported experiencing one or two items assessed in HFSSM. However, 67.3% of the overall sample (n=152) reported no experiences of food insecurity (i.e., affirmed no items in the HFSSM). Overall, participants affirmed 1.38±2.76 items in the HFSSM. Among those reporting any experience of food insecurity (n=74), participants affirmed, on average, 4.2±3.4 items.

There were statistically significant differences between food secure and insecure households on many attributes (Table 4.3). The proportion of participants diagnosed with T2DM (Food Insecure (FIS): 29.6%, Food Secure (FS): 14.8%; p-value: 0.02) was higher among those living in households that experienced food insecurity. Similarly, participants

more often reported low socioeconomic status (FS: 40.1%; FIS: 70.5%; p-value: 0.0003) and participation in at least one food assistance program (FS: 26.4%; FIS: 81.8%; p-value: <0.0001) were also more common among food insecure households than in food secure households. In contrast, participants in food secure households were more often female (FS: 56.0%; FIS: 47.7%; p-value: 0.3), non-Hispanic White (FS: 69.8%; FIS: 63.6%; p-value: 0.4), and were, on average, younger at the time of the cohort visit (FS: 18.6±4.7; FIS: 19.1±5.1; p-value: 0.6), however these differences were not statistically significant.

4.2.1.2 Sample Dietary Behaviors and Quality Characteristics

The daily caloric intake reported by YYA in this population was, on average, fairly low (1680.5±731.5; Table 4.4), ranging from 369.8 to 5161.7 kcal per day (data not shown). On average, reported caloric intake was -477.4 (range: -2123.2 to +2379.3 kcal; data not shown) less than estimated energy requirement, an age and gender-specific estimations based upon self-reported physical activity that ranging from 1600 to 3100 kcal per day(282). The caloric intake for the majority, over 75%, of these YYA did not meet the estimated energy requirement, including just over half of participants reporting a diet that did not meet the lowest estimated energy requirement (i.e., 1600 kcal per day).

Daily caloric intake differed significantly by food security status. Mean caloric intake was higher among YYA in food insecure households (FS: 1621.8±724.3; FIS: 1923.5±719.0; p-value: 0.01; Table 4.4). This, despite energy requirement estimates, on average, being comparable (FS: 2156.0±439.2; FIS: 2165.9±389.4; p-value: 0.9; data not shown).

There were significant differences in total daily intake of several food groups and nutrients across food security status (data not shown). Average daily servings of meat,

poultry, fish, and eggs (FS: 2.6±1.7; FIS: 3.2±1.5; p-value: 0.02) and sweets (FS: 12.6±11.1; FIS: 16.9±13.6; p-value: 0.03) were both higher among YYA experiencing food insecurity than those who were food secure. Similarly, the mean total intake (in grams) reported by YYA in food insecure households was higher for carbohydrates (FS:193.6±95.5; FIS: 229.6±104.8; p-value: 0.03), protein (FS:65.9±29.9; FIS: 77.1±32.5; p-value: 0.03), and fats (FS: 67.7±31.6; FIS: 80.4±30.5; p-value: 0.02), including saturated (FS: 22.8±11.1; FIS: 26.9±11.4; p-value: 0.03), monounsaturated (FS: 24.2±11.7; FIS: 28.9±10.9; p-value: 0.02), polyunsaturated (FS: 14.6±7.5; FIS: 17.2±6.6; p-value: 0.04), and *Trans* (FS: 2.2±1.3; FIS: 2.7±1.2; p-value: 0.01) fats. Additionally, daily total intake of cholesterol (in mg; FS:249.3±155.1; FIS: 312.3±181.7; p-value: 0.02), zinc (in mg; FS:9.1±4.3; FIS: 10.7±5.0; p-value: 0.04), and sodium (in mg; FS:2775.0±1279.5; FIS: 3343.7±1432.8; p-value: 0.01) were also, on average, higher among those who were experiencing food insecurity (data not shown). However, after standardizing by caloric intake, these differences were no longer statistically significant and many trends switched direction (Table 4.4).

Overall dietary quality in this sample was low (Table 4.4) and there was no one who had perfect adherence to the DASH diet, indicated by an overall adherence score of 80. The average overall score was 40.1±10.1, ranging from 16.7 to 62.2 (data not shown).

Adherence to the component scores was also quite low (Table 4.4). However, there was at least one participant with perfect adherence for most components (data not shown), aside from grains, more specifically high fiber grains (range: 0-4.2 out of 5), a subcomponent of total grains. The average DASH scores for fats and oils (7.9±3.5) and meats, poultry, fish, and eggs (6.4±3.9) were highest, but the average scores for total dairy

(5.3±3.0), vegetables (5.0±3.0), nuts, seeds, and legumes (4.7±4.5), total grains (2.7±1.4), and sweets (4.4±4.7) were around half of the maximum value, which was 10 for the components. The average score for the high-fiber grain sub-component (0.4±0.7; out of 5) was proportionally much lower than the other components, but fruit (3.6±2.8; out of 10) adherence was also quite low.

Adherence to the DASH diet differed by participants' food security status, but these differences were not statistically significant in most cases (Table 4.4). Overall, DASH diet adherence was slightly higher among YYA living in food secure households (FS: 40.7±10.0; FIS: 37.4±10.5; p-value: 0.06). Similar trends were seen in component scores for fats and oils, sweets, nuts, seeds, and legumes, and low-fat dairy. Scores were slightly higher among YYA in food secure households compared to food insecure, but these were not statistically significant. In contrast, scores for grains, fruits, and dairy were higher among YYA in food insecure households than food secure, but these too were not statistically significant. Variability in some of the component scores was quite large comparatively, most notably the nuts, seeds, and legumes and sweets components (Table 4.4).

In contrast, adherence to the meat, poultry, fish, and egg component differed by participants' food security status and this difference was statistically significant (Table 4.4). On average, the adherence score for the meat, poultry, fish, and egg component was higher among YYA in food secure households (FS: 6.7±3.9; FIS: 5.1±3.6; p-value: 0.01).

Despite low averages overall and by component scores, there were notable trends in adherence to specific components. Most participants, 91.6%, reported perfect adherence to at least one component, many reporting adherence to two (27.9%) or three (28.2%),

though some reported more (7.0%). The number of components with perfect adherence was, on average, higher among participants who were food secure (2.1±1.1; FIS: 1.5±1.2; p-value: 0.003). Most commonly this included fats and oils (66.4%), meats, poultry, fish, and eggs (38.5%), nuts, seeds, and legumes (34.1%), and sweets (33.6%). In contrast, no adherence (i.e., score=0) was common among other components. Most often this included sweets (48.2%) and nuts, seeds, and legumes (40.3%). About 75% of participants reported no adherence to at least one component, most often one (35.4%) or two (31.9%). In contrast to all other component scores, all participants reported at least partial adherence to the grain component score (range: 0.1-8.2; data not shown).

There were important differences in adherence across food insecurity status for two components: a) meats, poultry, fish, and eggs and b) fats and oils. For the meats, poultry, fish, and eggs component (p-value: 0.01), 43.4% of those who were food secure reported full adherence, 42.3% with partial and 14.3% with no adherence compared to 18.2%, 61.4%, and 20.5% among food insecure, respectively (data not shown). This is consistent with the DASH component score for the meats, poultry, fish, and eggs component (FS: 6.73±3.91; FIS: 5.10±3.64; p-value: 0.01; Table 4.4). For adherence to the fat and oil component (p-value: 0.03), 70.3% of those who were food secure with full adherence, 15.4% with partial and 14.3% with no adherence compared to 50.0%, 36.4%, and 13.6% among food insecure, respectively (data not shown). Although these differences were not statistically significant, there is a similar trend for the fats and oils DASH component score (FS: 8.13±3.41, FIS: 7.02±3.86; p-value: 0.06; Table 4.4).

4.2.1.3 Association of Food Security with Dietary Intake in Multivariate Models

4.2.1.3.1 Overall DASH Adherence

The relationship between adherence to DASH dietary recommendations and measures of food insecurity was inconsistent (Tables 4.5-4.8).

Standardized food security score (Table 4.5) was a statistically significant predictor of overall adherence to DASH dietary recommendations in the unadjusted model (β: -0.99; 95% CI: -1.77,-0.20; p:value: 0.01). However, this association (β: -0.35; 95% CI: -1.16,0.45; p-value: 0.4) attenuated after adjustment for participant age at time of clinic visit, clinic location, participation in food assistance, socioeconomic status, time since diabetes diagnosis, diabetes type, and participant sex. In contrast, dichotomous food security status (Table 4.6) was not a statistically significant predictor in either the crude (β: -3.25; 95% CI: -6.55,0.05; p-value: 0.054) or adjusted models (β:0.10; 95% CI:-3.34,3.53; p-value: 0.95).

There were similar trends in the associations of food security and categories of adherence to DASH dietary recommendations. Standardized food security score (Table 4.7) was a statistically significant predictor of highest adherence tertile in crude models (OR: 0.80; 95% CI: 0.65,0.98; p-value: 0.03) compared to lowest adherence. Again, this attenuated after adjustment (AOR: 0.89; 95% CI: 0.70,1.13; p-value: 0.3). Standardized food security score was not a significant models examining mid-range adherence compared to the lowest adherence tertiles (Table 4.7). Similar to continuous adherence measures, food security status was not a statistically significant predictor for overall DASH adherence tertile in any of the models examined (Table 4.8).

Notably, participating in food assistance was a statistically significant predictor of lower overall DASH score in models with standardized food security score ($\beta_{assistance}$: -4.19; 95%CI: -7.—25, -1.14; p-value: 0.01) and food insecurity ($\beta_{assistance}$: -4.55; 95%CI: -7.—19, -1.91; p-value: 0.001; data not shown). Given the bidirectional nature of the relationship between food security and participation in food assistance, additional analyses explored this relationship assuming the opposite relationship between food security and food assistance (i.e., without adjusting for food assistance). In these analyses, neither standardized food security score (β: -0.74; 95%CI: -1.51, 0.02-0.04; p-value: 0.06) nor food insecurity (β: -1.94; 95%CI: -5.16,1.28; p-value: 0.2) were statistically significant predictors of overall DASH score and implications due to changes in parameter estimates were minimal (data not shown).

4.2.1.3.2 Adherence to DASH Component Scores

There were no statistically significant associations between either measure of food security and most component scores that persisted after adjustment. This includes the component scores for grains, vegetables, fruits, dairy, nuts, seeds, and legumes, and fats and oils, either as a standardized food security score (Table 4.5) or food security status (Table 4.6).

One exception is the adherence score for the Sweets component, particularly with standardized food security score (Table 4.5). Although not statistically significant in the crude model (β: -0.32; 95% CI: -0.68, 0.05; p-value: 0.09), standardized food security score (β_{adj}: -0.38; 95% CI: -0.73, -0.02; p-value: 0.04) was a statistically significant predictor of adherence to the component for sweets after adjustment (Table 4.5). However, none of the associations with food security status were statistically significant (Table 4.6).

Only adherence score to meats, poultry, fish, and eggs recommendations was associated with food security, both as a standardized score (Table 4.5) and food security status (Table 4.6). For this component, higher scores are indicative of lower intake, which reflects DASH dietary guidance to limit intake of these types of foods. Standardized food insecurity score (β: -0.43; 95% CI: -0.73, -0.12; p-value: 0.01; Table 4.5) and food security status (β: -1.63; 95% CI: -2.89, -0.36; p-value: 0.01; Table 4.6) were statistically significant predictors of adherence score in crude models. However, these associations did not persist after adjustment for participant age at time of clinic visit, clinic location, participation in food assistance, socioeconomic status, time since diabetes diagnosis, diabetes type, and participant's sex.

There were similar trends when examining adherence to component-specific recommendations. High, compared to low, level adherence was not associated with either measure of food security including standardized food security score (Table 4.7) or food security status (Table 4.8) in any of the models for grains, vegetables, fruits, dairy, nuts, seeds, and legumes, and sweets adherence. Food security status (OR: 0.30; 95% CI: 0.12,0.73; p-value: 0.01), but not standardized score (OR: 0.89; 95% CI: 0.76-1.05; p-value: 0.2), was a predictor of high-level, compared to low-level, adherence to fat and oil recommendations in crude analyses. Again, this relationship attenuated after adjustment (AOR: 0.42; 95% CI: 0.15,1.16 p-value: 0.09).

Food security was a statistically significant predictor of high-level adherence to meat, poultry, fish, and egg recommendations, compared to low-level adherence. However, in this case, the relationship persisted adjustment. Standardized food security score (AOR: 0.74; 95% CI: 0.57, 0.98; p-value: 0.03; Table 4.7) was a statistically significant predictor

of high, compared to low, adherence to the meat, poultry, fish and egg component, even after adjustment for participant age at time of clinic visit, clinic location, participation in food assistance, socioeconomic status, time since diabetes diagnosis, diabetes type, and participant's sex.

Food security was not a statistically significant predictor for mid-level adherence of any component (Table 4.7-4.8).

4.2.2 Food Security and Electronic Media Use

There were 274 cohort participants who were diagnosed with diabetes at least 5 years prior to the start of SEARCH 3 at the Washington and South Carolina sites. Participants were excluded if they were missing information on key indicators such as electronic media use (i.e., weekend and weekday television or leisure-time computer use; n=25) and household food security (n=7). Participants were also excluded if they did not provided information on covariates, including socioeconomic status (i.e., no known income or education; n=6) and diabetes type (n=4) were also excluded. Clinic location and age information was available for all participants. As a result, the final analytic sample for electronic media use included 233 cohort-only participants.

4.2.2.1 Sample Characteristics

Characteristics of the analytic sample for electronic media use outcomes are shown in Table 4.9. The majority of this sample was female (55.4%, n=129), non-Hispanic White (68.2%, n=159), and diagnosed with T1DM (81.6%, n=190), lived in a household with two caregivers (60.4%, n=139), and did not participate in any food assistance programs (61.4%, n=143). On average, participants were 19.1±4.7 years old and have been diagnosed with diabetes for 101.7±26.6 months, which is slightly less than 8.5 years.

Although most of the analytic sample was food secure (79.8%, n=186), 20.2% of participants were experiencing food insecurity, including 6.4% experiencing very low food security (data not shown). Among the food secure, 15.6% were marginally food secure and reported experiencing one or two items assessed in the USDA's Household Food Security Survey Module (HFSSM). However, 67.3% of the overall sample (n=157) reported no experiences of food insecurity (i.e., affirmed no items in the HFSSM). Overall, participants affirmed experiencing 1.4 (±2.7) items in the HFSSM. Among those reporting any experience of food insecurity (n=76), participants affirmed, on average, 4.2±3.3 items (data not shown).

Many correlates were more common among food insecure households, compared to food secure households, and these differences were statistically significant (Table 4.9). The proportion of participants with T2DM was higher among households that were food insecure (FS: 15.1%; FIS: 31.9%; p-value: 0.01) than food secure households. Participants reporting low socioeconomic status (FS: 43.6%; FIS: 72.3%; p-value: 0.0004) and participation in any food assistance program (FS: 27.4%; FIS: 83.0%; p-value: <0.0001) were also more common among food insecure households than in food secure households. In contrast, participants in food secure households were more often female (FS: 57.5%; FIS: 46.8%; p-value: 0.2), non-Hispanic White (FS: 69.4%; FIS: 63.8%; p-value: 0.5), and recorded weights that were, on average, lower (FS: 74.1±25.5; FIS:79.3±29.9; p-value: 0.2), however none of these differences were statistically significant.

4.2.2.2 Sample Electronic Media Use Descriptive Characteristics

Electronic media engagement, including watching television and leisure computer use, behaviors are shown in Table 4.10. Most participants (59.2%) reported less than 4

hours of daily engagement in electronic media use including television watching and leisure-time computer use, but high-level engagement (i.e., 4+ hours daily) was relatively common (40.8%). Participants reported, on average, 3.7±2.3 hours of electronic media use, 26.2±16.3 hours weekly. Reported engagement was, on average, higher over the weekends (4.3±2.5 hours per day) compared to weekdays (3.5±2.4 hours per day; Table 4.10), a difference that was statistically significant (p-value: 0.0003; data not shown).

Overall, electronic media use was, on average, very similar among food secure (3.7±2.3 hours per day) and food insecure (3.8±2.5 hours per day) participants, the weekly averages only differing by about 30 minutes (FS: 26.1±16.0 hours per week; FIS: 26.6±17.6 hours per week). Notably, although not statistically significant, food secure participants reported longer average use of electronic media on weekends and food secure participants reported longer average use on weekday days (Table 4.10).

Although most participants (54.5%) reported high-level television use (i.e., 2+ hours daily), 45.5% reported low-level engagement (Table 4.10). Participants reported, on average, 2.1±1.4 hours of daily television use (15.0±9.8 hours weekly), with slightly higher averages reported on weekend days (2.5±1.6 hours per day) compared to weekdays (2.0±1.5 hours per day; Table 4.10), a difference that was statistically significant (p-value: 0.001; data not shown).

Overall, food insecure participants, on average, spent more time watching television (FS: 14.8±9.9; FIS:16.0±9.6 hours per week; p-value: 0.5), but this difference was not statistically significant (Table 4.10). Although not statistically significant, average time spent watching television was higher among food insecure participants during weekdays (in hours per day; FS: 2.0±1.4; FIS: 2.3±1.4; p-value: 0.3). In contrast, average

weekend television use was comparable for both groups (in hours per day; FS: 2.5±1.6; FIS: 2.5±1.6; Table 4.10).

Leisure-time computer use was low in this sample. Most participants, 64%, reported less than 2 hours of daily use (n=149) and approximately 20% of participants reported no leisure-time computer use (n=47). Participants reported, on average, 1.6±1.5 hours of daily leisure time computer use (11.1±10.6 hours weekly). Reported engagement was, on average, higher over the weekends (1.9±1.7) compared to weekdays (1.5±1.5; Table 4.10), a difference that was statistically significant (p-value: 0.02; data not shown).

In contrast to television use, food secure participants, on average, spent slightly more time each week engaging in leisure computer use (in hours per week; FS: 11.3±10.5; FIS: 10.6±11.1; p-value: 0.7). Although not statistically significant, the mean engagement in leisure computer use was higher for food secure participants on both weekdays (in hours per day; FS: 1.5±1.5; FIS: 1.4±1.6) and weekends (in hours per day; FS: 1.9±1.7; FIS: 1.7±1.7).

4.2.2.3 Association of Food Security with Electronic Media Use

4.2.2.3.1 Electronic Media Use

Standardized food security score was not a statistically significant predictor for average daily (β_{adj}: 0.01; 95% CI: -0.17-0.19, p-value: 0.9), weekday (β_{adj}: 0.04; 95% CI: -0.14-0.23, p-value: 0.6), or weekend (β_{adj}: -0.09; 95% CI: -0.29-0.11, p-value: 0.4) electronic media use (Table 4.11). Additionally, food security score was not a statistically significant predictor of high-level engagement (≥4 hour daily; AOR: 0.95, 95% CI: 0.80-1.14, p-value: 0.6; Table 4.13).

Notably, age and high socioeconomic status (SES) were statistically significant predictors of average daily (Age: β_{adj}: 0.09, 95% CI: 0.02, 0.15, p-value: 0.01; SES: β_{adj}: -0.69; 95% CI: -1.30, -0.09; p-value: 0.02) and weekday (Age: β_{adj}: 0.10, 95% CI: 0.03, 0.16, p-value: 0.01; SES: β_{adj}: -0.83, 95% CI: -1.44, -0.21, p-value: 0.01), but not weekend electronic media use (data not shown).

Similar to analyses including standardized food security score, food security status was not a statistically significant predictor for average daily (β_{adj}: -0.28; 95% CI: -1.01, 0.46, p-value: 0.5), weekday (β_{adj}: -0.22; 95% CI: -0.97, 0.53, p-value: 0.6), or weekend (β_{adj}: -0.46; 95% CI: -1.28, 0.37, p-value: 0.3) electronic media use (Table 4.12). Additionally, food security status was not a statistically significant predictor of high-level engagement (≥4 hour daily; AOR: 0.65, 95% CI: 0.32, 1.35, p-value: 0.2; Table 4.13).

Again, age and high socioeconomic status (SES) were statistically significant predictors of average daily (Age: β_{adj}: 0.09, 95% CI: 0.02-0.15, p-value: 0.01; SES: β_{adj}: -0.69, 95% CI: -1.3—0, -0.09, p-value: 0.02) and weekday (Age: β_{adj}: 0.10, 95% CI: 0.03-0.16, p-value: 0.01; SES: β_{adj}: -0.83, 95% CI: -1.44, -0.21, p-value: 0.01), but not weekend electronic media use (data not shown).

4.2.2.3.2 Television Use

Standardized food security score was not a statistically significant predictor for average daily (β_{adj}: 0.01, 95% CI: -0.09, 0.12, p-value: 0.8), weekday (β_{adj}: 0.03, 95% CI: -0.08, 0.14, p-value: 0.6), or weekend (β_{adj}: -0.04, 95% CI: -0.16, 0.08, p-value: 0.5) television use (Table 4.11). Similarly, food security score was not a statistically significant predictor of high-level engagement in television watching (≥2 hour daily; AOR: 1.12, 95% CI: 0.93-1.34, p-value: 0.2, Table 4.13).

In the adjusted models, age, clinic site, and high socioeconomic status (SES) were statistically significant predictors of average daily (Age: β_{adj}: 0.05, 95% CI: 0.01-0.09, p-value: 0.01; Site: β_{adj}: 0.42, 95% CI: 0.06, 0.78, p-value: 0.02; SES: β_{adj}: -0.51, 95% CI: -0.86, -0.15, p-value: 0.005) and weekday (Age: β_{adj}: 0.06, 95% CI: 0.01, 0.10, p-value: 0.01; Site: β_{adj}: 0.42, 95% CI: 0.04, 0.79, p-value: 0.03; SES: β_{adj}: -0.64, 95% CI: -1.00, -0.27, p-value: 0.001) television use, whereas only age (β_{adj}: 0.05, 95% CI: 0.01-0.09, p-value: 0.03) was a statistically significant predictor of weekend television use (data not shown).

Similarly, food security status was not a statistically significant predictor for average daily (β_{adj}: -0.03, 95% CI: -0.47, 0.40, p-value: 0.9), weekday (β_{adj}: 0.01, 95% CI: -0.44, 0.46, p-value: 0.97), or weekend (β_{adj}: -0.16, 95% CI: -0.65, 0.34, p-value: 0.5) television use (Table 4.12). Food insecurity was also not a statistically significant predictor of high-level television watching (≥2 hour daily; AOR: 1.57, 95% CI: 0.73, 3.35, p-value: 0.2, Table 4.13).

As with standardized food security score analyses, age, clinic site, and high socioeconomic status (SES) were statistically significant predictors of average daily (Age: β_{adj}: 0.05, 95% CI: 0.01, 0.09, p-value: 0.01; Site: β_{adj}: 0.41, 95% CI: 0.07, 0.79, p-value: 0.03; SES: β_{adj}: -0.52, 95% CI: -0.88, -0.16, p-value: 0.004) and weekday (Age: β_{adj}: 0.05, 95% CI: 0.01-0.10, p-value: 0.01; Site: β_{adj}: 0.41, 95% CI: 0.03, 0.78, p-value: 0.03; SES: β_{adj}: -0.66, 95% CI: -1.02, -0.29, p-value: 0.001) television use, whereas only age (β_{adj}: 0.05, 95% CI: 0.01-0.09, p-value: 0.03) was a statistically significant predictor of weekend television use (data not shown).

4.2.2.3.3 Leisure Computer Use

Standardized food security score was not a statistically significant predictor of average daily (β_{adj}: -0.01, 95% CI: -0.13, 0.12, p-value: 0.9), weekday (β_{adj}: 0.01, 95% CI: -0.11, 0.13, p-value: 0.8), or weekend (β_{adj}: -0.05, 95% CI: -0.19-0.08, p-value: 0.4) computer use (Table 4.11). Food security score was also not a statistically significant predictor of high-level computer use (≥2 hour daily; AOR: 0.85, 95% CI: 0.70, 1.02, p-value: 0.1; Table 4.13).

Again, similar to findings for standardize food security score, food security status was also not a statistically significant predictor of average daily (β_{adj}: -0.24, 95% CI: -0.74, 0.25, p-value: 0.3), weekday (β_{adj}: -0.23, 95% CI: -0.73, 0.27, p-value: 0.4), or weekend (β_{adj}: -0.30, 95% CI: -0.85, 0.26, p-value: 0.3) computer use (Table 4.12) nor was food insecurity a statistically significant predictor of high-level computer use (≥2 hour daily; AOR: 0.53, 95% CI: 0.25, 1.13, p-value: 0.1; Table 4.13).

Table 4.1. Sample[a] characteristics of SEARCH 3 participants at sites in South Carolina or Washington, including incident (n=92) and prevalent (n=263) diabetes cases, overall and stratified by diabetes type

	Overall	**Diabetes Type[b]**		
		Type 1 (T1DM)	**Type 2 (T2DM)**	**p-value[c]**
	n (%) or mean (sd)	n (%) or mean (sd)	n (%) or mean (sd)	
Population, n	**355**	**279**	**76**	-
Cohort	263 (74.1)	219 (78.5)	44 (57.9)	0.0003
Registry	92 (25.9)	60 (21.5)	32 (42.1)	-
Age at time of visit[d]				
0-17 years old	196 (55.2)	168 (60.2)	28 (36.8)	0.0003
18 years or older	159 (44.8)	111 (39.8)	48 (63.2)	-
Average, in years	*16.9 (5.5)*	*16.1 (5.5)*	*20.0 (4.7)*	*<0.0001*
Sex				
Female	185 (52.1)	144 (51.6)	41 (54.0)	0.7
Male	170 (47.9)	135 (48.4)	35 (46.1)	-
Clinic Location				
Carolina	149 (42.0)	95 (34.1)	54 (71.1)	<0.0001
Washington	206 (58.0)	184 (66.0)	22 (29.0)	-
Any Food Resource Program Participation[e]	**141 (39.8)**	**84 (30.1)**	**57 (76.0)**	**<0.0001**
Supplemental Nutrition Assistance Program (SNAP)	102 (29.1)	57 (20.6)	45 (61.6)	<0.0001

Special Supplemental Nutrition Program for Women, Infants, and Children (WIC)	27 (7.7)	16 (5.8)	11 (14.9)	0.009
National School Lunch Program	80 (23.3)	49 (17.9)	31 (44.9)	<0.0001
Emergency Resources (i.e., Food Pantry)	37 (10.5)	22 (7.9)	15 (20.3)	0.002
Household Food Insecurity				
Number of Affirmations	1.5 (3.0)	1.2 (2.7)	2.5 (3.6)	0.001
Standardized Score	1.0 (1.7)	0.8 (1.6)	1.7 (2.1)	0.0002
Food Security Status[f]				
Food Secure	279 (78.6)	231 (82.8)	48 (63.2)	0.0002
Food Insecure	76 (21.4)	48 (17.2)	28 (36.8)	-
Very Low Food Security	*27 (7.6)*	*18 (6.5)*	*9 (11.8)*	0.0009

[a]Participants (n=22) were excluded from the analytic sample due to missing or unknown diabetes type (n=4), household food security status (n=16), and age at visit (n=2).

[b]Diabetes type, as reported by provider.

[c]Using ANOVA or Pearson's Chi-Squared, as appropriate

[d]Age at visit is the age at the time of the SEARCH 3 visit.

[e]Additional participants were missing valid responses to program-specific participation in food assistance (n=22) including the Supplemental Nutritional Assistance Program (i.e., SNAP; n=5), the Special Supplemental Nutritional Program for Women, Infants, and Children (i.e., WIC; n=3), School Lunch or Breakfast (n=12), and emergency food resources (n=3).

[f]Food security status is determined by standardized score, which is calculated from number of affirmations on the USDA's Household Food Security Status Module (HFSSM). Participants were classified as food secure if standardized score <2.3, and, by definition, anyone affirming 3 or more items, were classified as food insecure. Among those who were food insecure, participants with

standardized scores over 4.5 were classified as very-low food secure, which includes those who affirm 8 or more items in households with children and 6 or more items in households without.

Table 4.2. Prevalence of food insecurity among youth and young adults who participated in SEARCH 3 at the South Carolina or Washington sites (n=355)[a] by diabetes type

	Diabetes Type[b]				p-value[c]
	Type 1 (T1DM)		Type 2 (T2DM)		
	Estimate	sd or 95% CI	Estimate	sd or 95% CI	
Overall, n	**279**	-	**76**	-	
Household Food Security					
Items Affirmed, avg.	1.2	2.7	2.5	3.6	0.001
Standardized Score, avg.	0.8	1.6	1.7	2.1	0.0002
Food Insecure, %	17.2	13.2-22.1	36.8	26.9-48.1	0.0002
Very Low Food Security, %	6.5	4.1-10.0	11.8	6.1-21.2	0.1
Among Females, n	*144*		*41*		
Items Affirmed, avg.	0.9	2.0	2.8	4.0	<0.0001
Standardized Score, avg.	0.7	1.3	1.8	2.2	<0.0001
Food Insecure, %	13.9	9.1-20.6	36.6	23.6-51.9	0.001
Very Low Food Security, %	3.5	1.3-8.1	14.6	6.5-28.8	0.02
Among Males, n	*135*		*35*		
Items Affirmed, avg.	1.6	3.2	2.1	3.3	0.4
Standardized Score, avg.	1.0	1.8	1.5	1.9	0.2
Food Insecure, %	20.7	14.7-28.4	37.1	23.2-53.7	0.04
Very Low Food Security, %	9.6	5.6-15.9	8.6	2.21-23.1	>0.99
Age at Visit[d]					
0-17 years old, n	***168***	**-**	***28***	-	
By Sex, n					
Female	83	-	15	-	

Male	85	-	13	-	
Household Food Security					
Items Affirmed, avg.	*1.4*	*3.0*	*2.8*	*4.1*	*0.04*
Among Females	1.1	2.4	3.3	4.8	0.009
Among Males	2.2	3.2	1.7	3.5	0.6
Standardized Score, avg.	*0.9*	*1.7*	*1.8*	*2.2*	*0.01*
Among Females	0.7	1.5	2.1	2.5	0.005
Among Males	1.0	2.0	1.5	1.9	0.4
Food Insecure, %	*19.0*	*13.8-25.7*	*39.3*	*23.5-57.6*	*0.02*
Among Females	15.7	9.3-25.1	33.3	15.0-58.5	0.1
Among Males	22.4	14.7-32.4	46.2	23.2-70.9	0.09
18 years or older, n	***111***	***-***	***48***	***-***	
By Sex, n					
Female	61	-	26	-	
Male	50	-	22	-	
Household Food Security					
Items Affirmed, avg.	*1.0*	*2.0*	*2.3*	*3.4*	*0.003*
Among Females	0.6	1.3	2.5	3.5	0.0004
Among Males	1.4	2.6	2.0	3.3	0.4
Standardized Score, avg.	*0.8*	*1.4*	*1.6*	*2.0*	*0.003*
Among Females	0.5	1.1	1.7	2.1	0.001
Among Males	1.0	1.6	1.5	1.9	0.3
Food Insecure, %	*14.4*	*9.0-22.2*	*35.4*	*23.4-49.6*	*0.003*
Among Females	11.5	5.4-22.1	38.5	22.4-57.5	0.004
Among Males	18.0	9.5-31.0	31.8	16.2-52.9	0.2

[a]Participants (n=22) were excluded from the analytic sample due to missing or unknown diabetes type (n=4), household food security status (n=16), and age at visit (n=2).

[b]Diabetes type as reported by provider.
[c]Using ANOVA or Pearson's Chi-Squared, as appropriate.
[d]Age at visit is the age at the time of the SEARCH 3 visit.

Table 4.3. Sample characteristics of the SEARCH 3 cohort members (n=226[a]) participating at sites in South Carolina or Washington included in the analytic sample for dietary quality

	Overall	Food Security Status		
		Secure	**Insecure**	**p-value[b]**
	n (%) or mean (sd)	n (%) or mean (sd)	n (%) or mean (sd)	
Population, n	**226**	**182**	**44**	-
Diabetes Type[c]				
Type 1 (T1DM)	186 (82.30)	155 (85.16)	31 (70.45)	0.02
Type 2 (T2DM)	40 (17.70)	27 (14.84)	13 (29.55)	-
Age				
At time of visit (y)	18.73 (4.79)	18.64 (4.74)	19.09 (5.07)	0.6
At time of diagnosis (y)	10.22 (4.42)	10.19 (4.47)	10.36 (4.24)	0.8
Time since diagnosis (m)	101.55 (26.41)	100.88 (26.44)	104.32 (26.43)	0.4
Anthropometrics[d]				
Body Mass Index (z-score)[e]	0.79 (1.19)	0.78 (1.13)	0.84 (1.37)	0.8
Weight (kg)	74.48 (26.64)	73.77 (25.99)	77.15 (29.12)	0.5
Sex				
Female	123 (54.42)	102 (56.04)	21 (47.73)	0.3
Male	103 (45.58)	80 (43.96)	23 (52.27)	**-**
Race and Ethnicity				
Non-Hispanic White	155 (68.58)	127 (69.78)	28 (63.64)	0.4
All Others	71 (31.42)	55 (30.22)	16 (36.36)	-

Asian or Pacific Islander	6 (2.65)	5 (2.75)	1 (2.27)	
Black or African American	50 (22.12)	38 (20.88)	12 (27.27)	
Hispanic	14 (6.19)	11 (6.04)	3 (6.82)	
Other	1 (0.44)	1 (0.55)	0 (0)	
Socioeconomic Status[f]				
High	122 (53.98)	109 (59.89)	13 (29.55)	0.0003
Income, $50k or higher	86 (47.51)	83 (58.04)	3 (7.89)	<0.0001
Education, Bachelor's or higher	89 (39.73)	78 (43.33)	11 (25.00)	0.03
Low	104 (46.02)	73 (40.11)	31 (70.45)	-
Household Structure[g]				
Two parents in household	138 (61.88)	115 (64.25)	23 (52.27)	0.1
Any other household structures	85 (38.12)	64 (35.75)	21 (47.73)	-
Clinic Location				
Carolina	101 (44.69)	80 (43.96)	21 (47.73)	0.7
Washington	125 (55.31)	102 (56.04)	23 (52.27)	-
Any Food Resource Program Participation[h]	**84 (37.17)**	**48 (26.37)**	**36 (81.82)**	**<0.0001**
Supplemental Nutrition Assistance Program (SNAP)	63 (28.25)	34 (18.89)	29 (67.44)	<0.0001
Special Supplemental Nutrition Program for Women, Infants, and Children (WIC)	15 (6.67)	8 (4.42)	7 (15.91)	0.01
National School Lunch Program	43 (19.91)	26 (14.61)	17 (44.74)	<0.0001
Emergency Resources (i.e., Food Pantry)	20 (8.93)	8 (4.40)	12 (28.57)	<0.0001

[a]A subset were missing information on a key indicator and, as a result, were excluded from analyses (n=48). This included participants with missing or unknown diabetes type (n=4), household food security status (n=7), socioeconomic status (i.e., income and education; n=6), food assistance participation (n=5), and dietary intake (n=35).
[b]Using ANOVA, Pearson's Chi-Squared, or Fisher's Exact, as appropriate.
[c]Diabetes type reported by provider, those with other or unknown diabetes type were excluded from this sample.
[d]There were n=27 participants with missing anthropometric measurements (i.e., weight and BMI).
[e]BMI z-score was imputed for participants 20 years and older.
[f]High socioeconomic status defined as annual income ≥$50,000 or educational attainment of a bachelor's degree or higher, low is defined as income and education not meeting those criteria with at least one valid response. This includes n=47 participants with missing or invalid entries for either income (n=45) or education (n=2).
[g]Of those included in the sample, n=3 had missing or invalid responses to household structure.
[h]Participation in any food assistance is defined as participation in SNAP, WIC, Free or Reduced School Lunch, or receiving emergency food (e.g., from a church, food pantry, soup kitchen) in the previous 12 months, those who did not participate and provided at least one valid response were categorized as not participating. This includes n=13 participants with at least one missing or invalid response (SNAP n=3, WIC n=1, School Lunch n=10, emergency food n=2).

Table 4.4. Descriptive characteristics of dietary intake in the analytic sample of SEARCH 3 cohort participants at sites in South Carolina or Washington (n=226)

	Overall	**Food Security Status**		
		Secure	**Insecure**	**p-value[a]**
	n (%) or mean (sd)	n (%) or mean (sd)	n (%) or mean (sd)	
Population, n	**226**	**182**	**44**	**-**
DASH Diet Score	**40.05 (10.13)**	**40.68 (9.97)**	**37.43 (10.48)**	**0.06**
Grains	2.67 (1.35)	2.61 (1.33)	2.94 (1.42)	0.1
Grain sub-score: Total Grains	2.32 (1.19)	2.26 (1.15)	2.56 (1.33)	0.1
Grain sub-score: High Fiber	0.35 (0.74)	0.34 (0.78)	0.38 (0.57)	0.7
Vegetables	5.04 (3.03)	5.04 (3.01)	5.03 (3.14)	0.98
Fruit	3.55 (2.78)	3.45 (2.73)	3.94 (2.99)	0.3
Dairy	5.28 (3.02)	5.30 (3.03)	5.23 (3.00)	0.9
Dairy sub-score: Total Dairy	2.87 (1.59)	2.85 (1.61)	2.96 (1.51)	0.7
Dairy sub-score: Low-Fat Dairy	2.41 (1.99)	2.44 (1.99)	2.26 (2.04)	0.6
Meats, Poultry, Fish, Eggs	6.41 (3.91)	6.73 (3.91)	5.10 (3.64)	0.01
Nuts, Seeds, Legumes	4.74 (4.52)	4.80 (4.49)	4.51 (4.68)	0.7
Fats and Oils	7.92 (3.52)	8.13 (3.41)	7.02 (3.86)	0.06
Sweets	4.44 (4.66)	4.63 (4.68)	3.66 (4.53)	0.2
Energy, kcal/d	**1680.54 (731.52)**	**1621.80 (724.27)**	**1923.51 (718.98)**	**0.01**
Fat, %	19.77 (5.54)	19.78 (5.38)	19.73 (6.20)	0.96
Saturated fat, %	33.24 (7.80)	33.31 (8.09)	32.93 (6.56)	0.8
Monounsaturated fat, %	28.73 (4.94)	28.63 (5.07)	29.18 (4.42)	0.5
Polyunsaturated fat, %	16.08 (4.79)	16.17 (4.98)	15.73 (3.96)	0.6

Carbohydrates, %	64.26 (8.82)	64.10 (8.43)	64.92 (10.37)	0.6
Protein, %	15.97 (4.53)	16.12 (4.34)	15.36 (5.25)	0.3
Food group, servings per 1000 kcal				
Grains	2.05 (0.73)	2.07 (0.73)	1.93 (0.71)	0.2
High Fiber	0.07 (0.14)	0.07 (0.15)	0.06 (0.10)	0.96
Vegetables	1.49 (1.22)	1.55 (1.29)	1.23 (0.85)	0.1
Fruits	1.07 (0.97)	1.08 (1.00)	0.99 (0.86)	0.6
Dairy	0.93 (0.59)	0.95 (0.60)	0.85 (0.55)	0.3
Low Fat Dairy	0.46 (0.53)	0.48 (0.55)	0.36 (0.44)	0.2
Meat, Poultry, Fish, Eggs	1.61 (0.70)	1.57 (0.69)	1.75 (0.74)	0.1
Nuts, Seeds, Legumes	0.55 (0.89)	0.56 (0.90)	0.52 (0.87)	0.8
Fats and Oils	1.65 (1.28)	1.62 (1.34)	1.77 (0.97)	0.5
Sweets	1.08 (0.75)	1.05 (0.75)	1.19 (0.78)	0.3
Nutrients, per 1000 kcal				
Total fat, g	41.81 (7.25)	41.69 (7.20)	42.34 (7.50)	0.6
Saturated fat, g	14.03 (2.94)	14.00 (2.90)	14.13 (3.16)	0.8
Monounsaturated fat, g	14.96 (3.19)	14.89 (3.22)	15.26 (3.10)	0.5
Polyunsaturated fat, g	9.07 (2.44)	9.06 (2.48)	9.10 (2.33)	0.9
Trans fat, g	1.33 (0.42)	1.30 (0.41)	1.43 (0.45)	0.08
Cholesterol, mg	154.46 (65.94)	152.42 (66.66)	162.87 (62.87)	0.3
Carbohydrates, g	119.07 (22.37)	119.45 (21.87)	117.53 (24.53)	0.6
Protein, g	40.87 (6.97)	40.91 (6.59)	40.67 (8.48)	0.8
Fiber, g	8.50 (3.31)	8.69 (3.49)	7.70 (2.29)	0.07
Calcium, mg	514.43 (173.47)	522.43 (178.96)	481.35 (145.83)	0.2
Magnesium, mg	132.30 (40.92)	134.23 (42.48)	124.33 (32.97)	0.2

	Potassium, mg	1306.79 (339.45)	1319.99 (347.61)	1252.21 (300.88)	0.2
	Sodium, mg	1735.59 (343.69)	1734.16 (339.71)	1741.50 (363.69)	0.9
	Iron, mg	7.60 (1.92)	7.71 (2.03)	7.13 (1.27)	0.07
	Zinc, mg	5.67 (1.15)	5.68 (1.13)	5.61 (1.23)	0.7
	Vitamin C, mg	46.22 (35.06)	46.75 (35.47)	44.01 (33.62)	0.6
	Vitamin E, mg	4.12 (2.04)	4.21 (2.18)	3.77 (1.28)	0.2

[a]Using ANOVA to compare mean intake by food security status.

Table 4.5. Parameter estimates and 95% Confidence Intervals (CI) for adherence to continuous DASH scores for each of the dietary outcomes, as predicted by standardized food security score, in crude and DAG-adjusted[a] models (n=226)

	β	95% CI	p-value
DASH Score[b]			
Crude	-0.99	(-1.77,-0.20)	0.01
Adjusted	-0.35	(-1.16,0.45)	0.4
Grains[c]			
Crude	0.05	(-0.06,0.15)	0.4
Adjusted	0.03	(-0.08,0.15)	0.6
Vegetables			
Crude	-0.05	(-0.29,0.19)	0.7
Adjusted	-0.02	(-0.28,0.24)	0.9
Fruits			
Crude	0.02	(-0.20,0.24)	0.9
Adjusted	0.04	(-0.20,0.28)	0.7
Dairy[d]			
Crude	-0.04	(-0.27,0.20)	0.8
Adjusted	0.12	(-0.12,0.35)	0.3
Meats, Poultry, Fish, Eggs			
Crude	-0.43	(-0.73,-0.12)	0.01
Adjusted	-0.24	(-0.56,0.08)	0.1
Nuts, Seeds, Legumes			
Crude	-0.06	(-0.41,0.30)	0.8
Adjusted	0.09	(-0.30,0.48)	0.7

Fats and Oils				
	Crude	-0.17	(-0.45,0.10)	0.2
	Adjusted	-0.00	(-0.30,0.29)	0.99
Sweets				
	Crude	-0.32	(-0.68,0.05)	0.09
	Adjusted	-0.38	(-0.73,-0.02)	0.04

[a]Adjusted models included participant age at visit (in years), clinic location (SC or WA), participation in any food assistance (Supplemental Nutrition Assistance Program (SNAP), the Special Supplemental Nutrition Assistance Program for Women, Infants, and Children (WIC), National School Lunch Program, or seeking out emergency food resources such as a food pantry), socioeconomic status (high vs low, high: participants reported an annual income ≥$50,000 or that they completed a bachelor's degree or higher), time since diabetes diagnosis (in months), diabetes type (T1DM or T2DM), and participant's sex (male or female).

[b]The overall score is an index composed of component and quality scores measuring eight food groups: total grain including high fiber, vegetable, fruit, total dairy including low-fat dairy, meat, poultry, fish, and eggs, nuts, seeds, and legumes, fats and oils, and sweets.

[c]The total grain component score includes adherence to high fiber recommendations in addition to recommendations around general intake

[d]The total dairy component score includes adherence to low-fat dairy recommendations in addition to recommendations around general intake

Table 4.6. Parameter estimates and 95% Confidence Intervals (CI) for adherence to continuous DASH scores for each of the dietary outcomes, as predicted by food security status, in crude and DAG-adjusted[a] models (n=226)

	β	95% CI	p-value
DASH Score[b]			
Crude	-3.25	(-6.55,0.05)	0.05
Adjusted	0.10	(-3.34,3.53)	0.95
Grains[c]			
Crude	0.33	(-0.11,0.78)	0.1
Adjusted	0.27	(-0.22,0.76)	0.3
Vegetables			
Crude	-0.01	(-1.01,0.98)	0.98
Adjusted	0.21	(-0.88,1.29)	0.7
Fruits			
Crude	0.49	(-0.42,1.40)	0.3
Adjusted	0.72	(-0.29,1.74)	0.2
Dairy[d]			
Crude	-0.07	(-1.06,0.92)	0.9
Adjusted	0.61	(-0.39,1.61)	0.2
Meats, Poultry, Fish, Eggs			
Crude	-1.63	(-2.89,-0.36)	0.01
Adjusted	-0.89	(-2.24,0.45)	0.2
Nuts, Seeds, Legumes			
Crude	-0.28	(-1.76,1.20)	0.7
Adjusted	0.44	(-1.21,2.10)	0.6

Fats and Oils			
Crude	-1.11	(-2.26,0.04)	0.06
Adjusted	-0.40	(-1.66, 0.86)	0.5
Sweets			
Crude	-0.97	(-2.49,0.56)	0.2
Adjusted	-0.87	(-2.39,0.65)	0.3

[a]Adjusted models included participant age at visit (in years), clinic location (SC or WA), participation in any food assistance (Supplemental Nutrition Assistance Program (SNAP), the Special Supplemental Nutrition Assistance Program for Women, Infants, and Children (WIC), National School Lunch Program, or seeking out emergency food resources such as a food pantry), socioeconomic status (high vs low, high: participants reported an annual income ≥$50,000 or that they completed a bachelor's degree or higher), time since diabetes diagnosis (in months), diabetes type (T1DM or T2DM), and participant's sex (male or female).

[b]The overall score is an index composed of component and quality scores measuring eight food groups: total grain including high fiber, vegetable, fruit, total dairy including low-fat dairy, meat, poultry, fish, and eggs, nuts, seeds, and legumes, fats and oils, and sweets.

[c]The total grain component score includes adherence to high fiber recommendations in addition to recommendations around general intake

[d]The total dairy component score includes adherence to low-fat dairy recommendations in addition to recommendations around general intake

Table 4.7. Odds ratios (ORs) estimates and 95% Confidence Intervals (CI) for high and mid-level adherence to the DASH diet, as predicted by standardized food security score, in crude and DAG-adjusted[a] models (n=226)

	High to Low Adherence			Mid to Low Adherence		
	OR	**95% CI**	**p-value**	**OR**	**95% CI**	**p-value**
DASH Score[b]						
Crude	0.80	(0.65,0.98)	0.03	0.84	(0.69,1.02)	0.1
Adjusted	0.89	(0.70,1.13)	0.3	0.94	(0.75,1.18)	0.7
Grains[c]						
Crude	1.04	(0.86,1.27)	0.7	1.07	(0.88,1.31)	0.5
Adjusted	1.00	(0.80,1.24)	0.97	1.13	(0.89,1.43)	0.3
Vegetables[d]						
Crude	0.99	(0.82,1.18)	0.9	0.93	(0.76,1.13)	0.5
Adjusted	0.99	(0.80,1.21)	0.9	0.95	(0.76,1.18)	0.6
Fruits[e]						
Crude	1.01	(0.84,1.22)	0.9	0.90	(0.74,1.11)	0.3
Adjusted	1.02	(0.82,1.27)	0.9	0.83	(0.65,1.05)	0.1
Dairy[f]						
Crude	0.96	(0.80,1.16)	0.7	0.86	(0.70,1.06)	0.1
Adjusted	1.08	(0.84,1.40)	0.6	0.94	(0.74,1.19)	0.6
Meats, Poultry, Fish, Eggs[g]						
Crude	0.70	(0.55,0.89)	0.003	1.02	(0.85,1.22)	0.8
Adjusted	0.74	(0.57,0.98)	0.03	1.06	(0.86,1.31)	0.6
Nuts, Seeds, Legumes[h]						

Crude	0.94	(0.79,1.13)	0.5	0.90	(0.73,1.11)	0.3
Adjusted	1.02	(0.83,1.26)	0.8	0.89	(0.70,1.13)	0.3
Fats and Oils[i]						
Crude	0.89	(0.76,1.05)	0.2	-	-	-
Adjusted	0.97	(0.80,1.16)	0.7	-	-	-
Sweets[j]						
Crude	0.88	(0.72,1.07)	0.2	1.04	(0.85,1.28)	0.7
Adjusted	0.83	(0.65,1.06)	0.1	1.01	(0.78,1.30)	0.9

[a]Adjusted models included participant age at visit (in years), clinic location (SC or WA), participation in any food assistance (Supplemental Nutrition Assistance Program (SNAP), the Special Supplemental Nutrition Assistance Program for Women, Infants, and Children (WIC), National School Lunch Program, or seeking out emergency food resources such as a food pantry), socioeconomic status (high vs low, high: participants reported an annual income ≥$50,000 or that they completed a bachelor's degree or higher), time since diabetes diagnosis (in months), diabetes type (T1DM or T2DM), and participant's sex (male or female).

[b]The overall score is an index composed of component and quality scores measuring eight food groups: total grain including high fiber, vegetable, fruit, total dairy including low-fat dairy, meat, poultry, fish, and eggs, nuts, seeds, and legumes, fats and oils, and sweets. Adherence tertiles included low (range: 16.7-35.7; n=75), mid (range: 36.0-45.5; n=76), and high (range: 45.6-62.2; n=75) level adherence to dietary guidance.

[c]The total grain component score includes adherence to high fiber recommendations in addition to recommendations around general intake. Adherence tertiles included low (range: 0.1-1.8; n=75), mid (range: 1.9-3.2; n=76), and high (range: 3.2-8.2; n=75) level adherence to dietary guidance for grains.

[d]Adherence tertiles included low (range: 0-3.3; n=75), mid (range: 3.3-6.2; n=76), and high (range: 6.3-10.0; n=75) level adherence to dietary guidance for vegetables.

[e]Adherence tertiles included low (range: 0-1.8; n=75), mid (range: 1.8-4.2; n=76), and high (range: 4.3-10.0; n=75) level adherence to dietary guidance for fruit.

[f]The total dairy component score includes adherence to low-fat dairy recommendations in addition to recommendations around general intake. Adherence tertiles included low (range: 0-4.0; n=75), mid (range: 4.0-6.9; n=75), and high (range: 6.9-10.0; n=76) level adherence to dietary guidance for dairy.
[g]Results related to meats, poultry, fish, and egg adherence tertiles should be interpreted with caution due to uneven distribution and homogeneity among the high-level adherence group. Adherence tertiles included low (range: 0-4.6; n=75), mid (range: 4.8-9.9; n=64), and high (range: 10-10; n=87) level adherence to dietary guidance for meats, poultry, fish, and eggs.
[h]Results related to nuts, seeds, and legumes adherence tertiles should be interpreted with caution due to uneven distribution and homogeneity among the high- and low-level adherence groups. Adherence tertiles included low (range: 0-0; n=91), mid (range: 1.3-10; n=58), and high (range: 10-10; n=77) level adherence to dietary guidance for nuts, seeds, and legumes.
[i]Due to homogeneity, fat and oil intake tertiles could not be created. Still, results should be interpreted with caution due to uneven distribution and homogeneity among the high-level adherence group. Adherence groups included low (range: 0-9.9; n=76) and high (range: 10-10; n=150) level adherence to dietary guidance for fats and oils.
[j]Results related to sweets adherence tertiles should be interpreted with caution due to uneven distribution and homogeneity among the high- and low-level adherence groups. Adherence tertiles included low (range: 0-0; n=109), mid (range: <0.1-9.3; n=41), and high (range: 10-10; n=76) level adherence to dietary guidance for sweets.

Table 4.8. Odds ratios (ORs) estimates and 95% Confidence Intervals (CI) for high and mid-level adherence to the DASH diet, as predicted by food security status, in crude and DAG-adjusted[a] models (n=226)

	High to Low Adherence			Mid to Low Adherence		
	OR	**95% CI**	**p-value**	**OR**	**95% CI**	**p-value**
DASH Score[b]						
Crude	0.47	(0.21,1.07)	0.07	0.57	(0.26,1.25)	0.2
Adjusted	0.98	(0.35,2.76)	0.97	1.14	(0.44,2.93)	0.8
Grains[c]						
Crude	1.31	(0.57,3.03)	0.5	1.51	(0.67,3.43)	0.3
Adjusted	0.99	(0.38,2.65)	0.99	2.03	(0.75,5.51)	0.2
Vegetables[d]						
Crude	1.17	(0.54,2.57)	0.7	0.75	(0.33,1.73)	0.5
Adjusted	1.30	(0.52,3.27)	0.6	0.89	(0.35,2.29)	0.8
Fruits[e]						
Crude	1.38	(0.63,3.02)	0.4	0.82	(0.35,1.91)	0.6
Adjusted	1.65	(0.65,4.21)	0.3	0.64	(0.24,1.71)	0.4
Dairy[f]						
Crude	0.91	(0.41,2.00)	0.8	0.77	(0.34,1.75)	0.5
Adjusted	1.61	(0.53,4.93)	0.4	1.33	(0.50,3.56)	0.6
Meats, Poultry, Fish, Eggs[g]						
Crude	0.30	(0.12,0.73)	0.01	1.07	(0.50,2.28)	0.9
Adjusted	0.42	(0.15,1.16)	0.09	1.22	(0.48,3.11)	0.7
Nuts, Seeds, Legumes[h]						
Crude	0.74	(0.35,1.58)	0.4	0.61	(0.26,1.45)	0.3

Adjusted	1.10	(0.45,2.71)	0.8	0.60	(0.22,1.65)	0.3
Fats and Oils[i]						
Crude	0.42	(0.22,0.83)	0.01	-	-	-
Adjusted	0.54	(0.25,1.18)	0.1	-	-	-
Sweets[j]						
Crude	0.70	(0.32,1.51)	0.4	1.05	(0.44,2.51)	0.9
Adjusted	0.77	(0.28,2.11)	0.6	0.96	(0.32,2.78)	0.9

[a]Adjusted models included participant age at visit (in years), clinic location (SC or WA), participation in any food assistance (Supplemental Nutrition Assistance Program (SNAP), the Special Supplemental Nutrition Assistance Program for Women, Infants, and Children (WIC), National School Lunch Program, or seeking out emergency food resources such as a food pantry), socioeconomic status (high vs low, high: participants reported an annual income ≥$50,000 or that they completed a bachelor's degree or higher), time since diabetes diagnosis (in months), diabetes type (T1DM or T2DM), and participant's sex (male or female).

[b]The overall score is an index composed of component and quality scores measuring eight food groups: total grain including high fiber, vegetable, fruit, total dairy including low-fat dairy, meat, poultry, fish, and eggs, nuts, seeds, and legumes, fats and oils, and sweets. Adherence tertiles included low (range: 16.7-35.7; n=75), mid (range: 36.0-45.5; n=76), and high (range: 45.6-62.2; n=75) level adherence to dietary guidance.

[c]The total grain component score includes adherence to high fiber recommendations in addition to recommendations around general intake. Adherence tertiles included low (range: 0.1-1.8; n=75), mid (range: 1.9-3.2; n=76), and high (range: 3.2-8.2; n=75) level adherence to dietary guidance for grains.

[d]Adherence tertiles included low (range: 0-3.3; n=75), mid (range: 3.3-6.2; n=76), and high (range: 6.3-10.0; n=75) level adherence to dietary guidance for vegetables.

[e]Adherence tertiles included low (range: 0-1.8; n=75), mid (range: 1.8-4.2; n=76), and high (range: 4.3-10.0; n=75) level adherence to dietary guidance for fruit.

[f]The total dairy component score includes adherence to low-fat dairy recommendations in addition to recommendations around general intake. Adherence tertiles included low (range: 0-4.0; n=75), mid (range: 4.0-6.9; n=75), and high (range: 6.9-10.0; n=76) level adherence to dietary guidance for dairy.
[g]Results related to meats, poultry, fish, and egg adherence tertiles should be interpreted with caution due to uneven distribution and homogeneity among the high-level adherence group. Adherence tertiles included low (range: 0-4.6; n=75), mid (range: 4.8-9.9; n=64), and high (range: 10-10; n=87) level adherence to dietary guidance for meats, poultry, fish, and eggs.
[h]Results related to nuts, seeds, and legumes adherence tertiles should be interpreted with caution due to uneven distribution and homogeneity among the high- and low-level adherence groups. Adherence tertiles included low (range: 0-0; n=91), mid (range: 1.3-10; n=58), and high (range: 10-10; n=77) level adherence to dietary guidance for nuts, seeds, and legumes.
[i]Due to homogeneity, fat and oil intake tertiles could not be created. Still, results should be interpreted with caution due to uneven distribution and homogeneity among the high-level adherence group. Adherence groups included low (range: 0-9.9; n=76) and high (range: 10-10; n=150) level adherence to dietary guidance for fats and oils.
[j]Results related to sweets adherence tertiles should be interpreted with caution due to uneven distribution and homogeneity among the high- and low-level adherence groups. Adherence tertiles included low (range: 0-0; n=109), mid (range: <0.1-9.3; n=41), and high (range: 10-10; n=76) level adherence to dietary guidance for sweets.

Table 4.9. Sample characteristics of the SEARCH 3 cohort members (n=233[a]) participating at sites in South Carolina or Washington included in the analytic sample for electronic media engagement

	Overall	Food Security Status		
		Secure	Insecure	p-value[b]
	n (%) or mean (sd)	n (%) or mean (sd)	n (%) or mean (sd)	
Population, n	**233**	**186**	**47**	-
Diabetes Type[c]				
Type 1 (T1DM)	190 (81.55)	158 (84.95)	32 (68.09)	0.01
Type 2 (T2DM)	43 (18.45)	28 (15.05)	15 (31.91)	-
Age				
At time of visit (y)	19.09 (4.67)	19.06 (4.61)	19.22 (4.98)	0.8
At time of diagnosis (y)	10.58 (4.26)	10.57 (4.27)	10.61 (4.23)	0.95
Time since diagnosis (m)	101.65 (26.55)	101.34 (26.57)	102.85 (26.72)	0.7
Anthropometrics[d]				
Body Mass Index (z-score)[e]	0.81 (1.19)	0.79 (1.14)	0.91 (1.36)	0.5
Weight (kg)	75.21 (26.51)	74.10 (25.50)	79.30 (29.93)	0.2
Sex				
Female	129 (55.36)	107 (57.53)	22 (46.81)	0.2
Male	104 (44.64)	79 (42.47)	25 (53.19)	-
Race and Ethnicity				
Non-Hispanic White	159 (68.24)	129 (69.35)	30 (63.83)	0.5

All Others	74 (31.76)	57 (30.65)	17 (36.17)	-
Asian or Pacific Islander	6 (2.58)	5 (2.69)	1 (2.13)	
Black or African American	54 (23.18)	41 (22.04)	13 (27.66)	
Hispanic	13 (5.58)	10 (5.38)	3 (6.38)	
Other	1 (0.43)	1 (0.54)	0 (0.00)	
Socioeconomic Status[f]				
High	118 (50.64)	105 (56.45)	13 (27.66)	0.0004
Income, $50k or higher	83 (45.11)	80 (55.56)	3 (7.50)	<0.0001
Education, Bachelor's or higher	86 (37.23)	75 (40.76)	11 (23.40)	0.03
Low	115 (49.36)	81 (43.55)	34 (72.34)	-
Household Structure[g]				
Two parents in household	139 (60.43)	115 (62.84)	24 (51.06)	0.1
Any other household structures	91 (39.57)	68 (37.16)	23 (48.94)	-
Clinic Location				
Carolina	110 (47.21)	87 (46.77)	23 (48.94)	0.8
Washington	123 (52.79)	99 (53.23)	24 (51.06)	-
Any Food Resource Program Participation[h]	**90 (38.63)**	**51 (27.42)**	**39 (82.98)**	**<0.0001**
Supplemental Nutrition Assistance Program (SNAP)	67 (29.13)	35 (19.02)	32 (69.57)	<0.0001
Special Supplemental Nutrition Program for Women, Infants, and Children (WIC)	15 (6.49)	8 (4.35)	7 (14.89)	0.02
National School Lunch Program	44 (19.73)	27 (14.84)	17 (41.46)	0.0001
Emergency Resources (i.e., Food Pantry)	21 (9.09)	9 (4.84)	12 (26.67)	<0.0001

[a]A subset were missing information on a key indicator and, as a result, were excluded from analyses (n=41). This included participants with missing or unknown diabetes type (n=4), household food security status (n=7), socioeconomic status (i.e., income and education; n=6), food assistance participation (n=5), and electronic media consumption (i.e., television and leisure-time computer use; n=25).
[b]Using ANOVA, Pearson's Chi-Squared, or Fisher's Exact, as appropriate.
[c]Diabetes type reported by provider, those with other or unknown diabetes type were excluded from this sample.
[d]There were n=27 participants with missing anthropometric measurements (i.e., weight and BMI).
[e]BMI z-score was imputed for participants 20 years and older.
[f]High socioeconomic status defined as annual income ≥$50,000 or educational attainment of a bachelor's degree or higher, low is defined as income and education not meeting those criteria with at least one valid response. This includes n=51 participants with missing or invalid entries for either income (n=49) or education (n=2).
[g]Of those included in the sample, n=3 had missing or invalid responses to household structure.
[h]Participation in any food assistance is defined as participation in SNAP, WIC, Free or Reduced School Lunch, or receiving emergency food (e.g., from a church, food pantry, soup kitchen) in the previous 12 months, those who did not participate and provided at least one valid response were categorized as not participating. This includes n=14 participants with at least one missing or invalid response (SNAP n=3, WIC n=2, School Lunch n=10, emergency food n=2).

Table 4.10. Descriptive characteristics of self-reported electronic media engagement in the analytic sample of SEARCH 3 cohort participants at sites in South Carolina or Washington (n=233[a])

	Overall	Food Security Status		
		Secure	Insecure	p-value
	n (%) or mean (sd)	n (%) or mean (sd)	n (%) or mean (sd)	
Population, n	**233**	**186**	**47**	-
Electronic Media Engagement[c]				
Weekly[d]	26.18 (16.26)	26.08 (15.95)	26.59 (17.59)	0.8
Daily Average[e]	3.74 (2.32)	3.73 (2.28)	3.80 (2.51)	0.8
Weekday, per day	3.51 (2.39)	3.48 (2.35)	3.63 (2.56)	0.7
Weekend[f], per day	4.34 (2.55)	4.37 (2.50)	4.22 (2.76)	0.7
Daily Electronic Media Engagement Level				
Low, <4 hours	138 (59.23)	109 (58.60)	29 (61.70)	0.7
High, ≥4 hours	95 (40.77)	77 (41.40)	18 (38.30)	-
Watching Television, hours				
Weekly[d]	15.05 (9.81)	14.81 (9.88)	15.99 (9.57)	0.5
Daily Average[e]	2.15 (1.40)	2.12 (1.41)	2.28 (1.37)	0.5
Weekday, per day	2.02 (1.46)	1.97 (1.48)	2.20 (1.41)	0.3
Weekend[f], per day	2.49 (1.56)	2.49 (1.55)	2.49 (1.59)	0.99
Daily Television Use Level				
Low, <2 hours	106 (45.49)	90 (48.39)	16 (34.04)	0.08
High, ≥2 hours	127 (54.51)	96 (51.61)	31 (65.96)	-
Leisure Computer Use, hours				

Weekly[d]		11.13 (10.60)	11.27 (10.50)	10.60 (11.08)	0.7
Daily Average[e]		1.59 (1.51)	1.61 (1.50)	1.51 (1.58)	0.7
	Weekday, per day	1.49 (1.52)	1.51 (1.51)	1.43 (1.59)	0.7
	Weekend[f], per day	1.85 (1.68)	1.88 (1.68)	1.73 (1.70)	0.6
Daily Leisure Computer Use Level					
	Low, <2 hours	149 (63.95)	116 (62.37)	33 (70.21)	0.3
	High, ≥2 hours	84 (36.05)	70 (37.63)	14 (29.79)	-
Activity Level[g]					
Active		24 (10.30)	21 (11.29)	3 (6.38)	0.3
Low Active		58 (24.89)	49 (26.34)	9 (19.15)	-
Sedentary		151 (64.81)	116 (62.37)	35 (74.47)	-
Physical Activity[h], days per week					
Vigorous		2.72 (2.18)	2.82 (2.22)	2.30 (2.00)	0.1
Moderate		2.53 (2.30)	2.66 (2.35)	2.02 (2.05)	0.1
Strengthening		1.54 (1.80)	1.67 (1.81)	1.02 (1.70)	0.03

[a]A subset were missing information on a key indicator and, as a result, were excluded from analyses (n=41). This included participants with missing or unknown diabetes type (n=4), household food security status (n=7), socioeconomic status (i.e., income and education; n=6), food assistance participation (n=5), and electronic media consumption (i.e., television and leisure-time computer use; n=25).

[b]Using ANOVA, Pearson's Chi-Squared, or Fisher's Exact, as appropriate.

[c]Electronic media use is calculated as the time spent watching television and leisure computer use, combined.

[d]Time spent watching television and using the computer were each assessed both on the weekend and, separately, during the week. Average weekly use was calculated by taking a weighted sum, *2*(hoursweekend)+5*(hoursweekday)*. If average weekend use was missing (n=1), weekly average was calculated based upon weekday use.

[e]Average daily use is calculated as the weekly time spent watching television or leisure computer use, divided by 7 days.
[f]There was n=1 participant with unknown weekend television and leisure time computer use on weekends.
[g]Participants were asked about the number of days they participated in vigorous and moderate physical activities in the previous week. Participants were classified as active if they reported participating in activities both moderate and vigorous physical activities five or more days per week. Participants were classified as low active if they reported five or more days of either moderate or physical activity. Participants were classified as sedentary if they reported participating in less than five days of both moderate and vigorous physical activity.
[h]Number of days participating in moderate physical activity was determined by participant's response to number of days exercised or participated in at least 30 minutes of physical activity that didn't make them sweat or breath hard. Vigorous physical activity was determined by the number of days where respondent participated in 20 or more minutes of physical activity that made them sweat or breath hard. Strengthening includes the number of days that the respondent did exercises to strengthen or tone muscles.

Table 4.11. Parameter estimates and 95% Confidence Intervals (CI) of average time (in hours) spent using electronic media[a], as predicted by standardized food security score, in crude and DAG-adjusted[b] models (n=233)

	Daily			**Weekday**			**Weekend**		
	β	**95% CI**	**p-value**	***β***	**95% CI**	**p-value**	***β***	**95% CI**	**p-value**
Electronic Media Use[a]									
Crude	0.09	(-0.09,0.27)	0.3	0.13	(-0.06,0.31)	0.2	-0.01	(-0.21,0.19)	0.9
Adjusted	0.01	(-0.17,0.19)	0.9	0.04	(-0.14,0.23)	0.6	-0.09	(-0.29,0.11)	0.4
Television Watching									
Crude	0.06	(-0.05,0.17)	0.3	0.08	(-0.03,0.19)	0.2	0.00	(-0.12,0.12)	0.99
Adjusted	0.01	(-0.09,0.12)	0.8	0.03	(-0.08,0.14)	0.6	-0.04	(-0.16,0.08)	0.5
Leisure Computer Use									
Crude	0.03	(-0.08,0.15)	0.6	0.05	(-0.07,0.17)	0.4	-0.01	(-0.14,0.12)	0.9
Adjusted	-0.01	(-0.13,0.12)	0.9	0.01	(-0.11,0.13)	0.8	-0.05	(-0.19,0.08)	0.4

[a]Electronic media use is calculated as the time spent watching television and leisure computer use, combined.

[b]Adjusted models included participant age at time of clinic visit (in years), clinic location (SC or WA), socioeconomic status (high vs low, high: participants reported an annual income ≥$50,000 or that they completed a bachelor's degree or higher), diabetes type (T1DM or T2DM), and participant's sex (male or female).

Table 4.12. Parameter estimates and 95% Confidence Intervals (CI) of average time (in hours) spent using electronic media[a], as predicted by food security status, in crude and DAG-adjusted[b] models (n=233)

	Daily			**Weekday**			**Weekend**		
	β	**95% CI**	**p-value**	***β***	**95% CI**	**p-value**	***β***	**95% CI**	**p-value**
Electronic Media Use[a]									
Crude	0.07	(-0.67,0.81)	0.8	0.15	(-0.61,0.91)	0.7	-0.14	(-0.96,0.67)	0.7
Adjusted	-0.28	(-1.01,0.46)	0.5	-0.22	(-0.97,0.53)	0.6	-0.46	(-1.28,0.37)	0.3
Television Watching									
Crude	0.17	(-0.28,0.62)	0.5	0.23	(-0.24,0.70)	0.3	0.00	(-0.49,0.50)	0.99
Adjusted	-0.03	(-0.47,0.40)	0.9	0.01	(-0.44,0.46)	0.97	-0.16	(-0.65,0.34)	0.5
Leisure Computer Use									
Crude	-0.10	(-0.58,0.39)	0.7	-0.08	(-0.57,0.41)	0.7	-0.15	(-0.68,0.39)	0.6
Adjusted	-0.24	(-0.74,0.25)	0.3	-0.23	(-0.73,0.27)	0.4	-0.30	(-0.85,0.26)	0.3

[a]Electronic media use is calculated as the time spent watching television and leisure computer use, combined.

[b]Adjusted models included participant age at time of clinic visit (in years), clinic location (SC or WA), socioeconomic status (high vs low, high: participants reported an annual income ≥$50,000 or that they completed a bachelor's degree or higher), diabetes type (T1DM or T2DM), and participant's sex (male or female).

Table 4.13. Odds ratio and 95% Confidence Intervals (CI) of high electronic media use[a], as predicted by food security, both standardized score and food security status, in crude and DAG-adjusted[b] models (n=233)

	Standardized Score			Food Insecurity		
	OR	**95% CI**	**p-value**	**OR**	**95% CI**	**p-value**
Electronic Media Use[a]						
Crude	1.02	(0.87,1.19)	0.8	0.88	(0.46,1.69)	0.7
Adjusted	0.95	(0.80,1.14)	0.6	0.65	(0.32,1.35)	0.2
Television Watching						
Crude	1.16	(0.98,1.36)	0.08	1.82	(0.93,3.54)	0.08
Adjusted	1.12	(0.93,1.34)	0.2	1.57	(0.73,3.35)	0.2
Leisure Computer Use						
Crude	0.93	(0.78,1.10)	0.4	0.70	(0.35,1.40)	0.3
Adjusted	0.85	(0.70,1.02)	0.1	0.53	(0.25,1.13)	0.1

[a]Electronic media use is calculated as the time spent watching television and leisure computer use, combined. Electronic media is classified as high if participants report over 4 hours of average daily use. Television and Computer are each classified as high if participants report over 2 hours of average use.

[b]Adjusted models included participant age at time of clinic visit (in years), clinic location (SC or WA), socioeconomic status (high vs low, high: participants reported an annual income ≥$50,000 or that they completed a bachelor's degree or higher), diabetes type (T1DM or T2DM), and participant’s sex (male or female).

CHAPTER 5: DISCUSSION

5.1 Specific Aim 1 (SA1)

In this pooled population of youth and young adults (YYA) with youth-onset T1DM and T2DM, 21.4% experienced food insecurity, including 7.6% reporting very low food security. Most of the sample was food secure (78.6%; n=279), which includes 67.6% (n=240), of participants were completely food secure and did not report any experiences with food insecurity and 14% (n=39) of participants who were marginally food secure, reporting that they experienced one or two of the items assessed in the HFSSM. In total, 32.4% reported that they experienced some form of food insecurity (i.e., affirmed at least one item in the HFSSM). In other words, almost 1 in 3 YYA with diabetes were living in a household that had some level of concern about having enough money for food.

Food insecurity in this population was much higher than national estimates. In 2015, the estimated prevalence for household food insecurity was 12.7% across the United States (US). The reported prevalence for the general population in South Carolina (SC; 13.2%) and Washington (WA; 12.9%), the sites that participated in the SEARCH Food Security Ancillary Pilot Study(20). In contrast, 21.4% of this sample was experiencing food insecurity (Table 4.1), including 23.5% at the SC site and 19.9% at the WA site (data not shown). Very low food security in this population of youth and young adults with diabetes (7.6%; SC: 7.4%; WA: 7.8%) was also higher than national prevalence estimates in the general population (US: 5.4%; SC: 4.6%; WA: 4.8%)(20).

This is supported by previous research, which also found that food insecurity is more common among populations with diabetes. In a national sample of Canadians 12 years and older, 9.3% (95% CI: 8.2-10.4) who reported having diabetes experienced food insecurity compared to 6.8% (95% CI: 6.5-7.0) of those without(37). Similar analyses found that food insecurity was more common among adults with diabetes in Alberta (15.0%) and families of children with diabetes in Nova Scotia (21.9%) compared to the general populations in those areas (Alberta: 5.6%; Nova Scotia: 14.6%)(51, 52). Further, severe food insecurity was substantially higher (6.7%) than population estimates (1.2%) (51), supporting the finding that populations with diabetes may be likely to experience more severe conditions of food insecurity.

In this population of YYA with diabetes, food insecurity was associated with diabetes type. Food insecurity was more common among participants with T2DM (36.8%; 95% CI: 26.9-48.1) compared to those with T1DM (17.2%; 95% CI: 13.2-22.1; Table 4.2), and the proportion of participants experiencing very low food security was almost double (T2DM: 11.8%, 95% CI: 6.1-21.2; T1DM: 6.5%, 95% CI: 4.1-10.0; Table 4.2). These findings could suggest that YYA with T2DM may be at increased risk of food insecurity.

The results presented here are consistent with analyses in similar cohorts. In SEARCH 4, which expanded upon the cohort presented here with more recent data, collected between 2016 and 2019, from additional coordinating center sites. Malik et al. (2021) found that 19.7% of the SEARCH 4 cohort were experiencing food insecurity, including 8.5% experiencing very low food security. SEARCH 4. In SEARCH 4, experiencing food insecurity was more frequent among YYA with T2DM (30.7%; 95% CI: 26.1-35.3) than those with T1DM (17.7%; 95% CI: 16.1-19.3). Moreover, 12.8% of

YYA with T2DM experienced very low food security compared to 7.8% of YYA with T1DM in SEARCH 4(292).

Male participants more often reported experiencing food insecurity (Table 4.2). Among those with T1DM, 20.7% (95% CI: 14.7-28.4) of male participants were food insecure compared to 13.9% (95% CI: 9.1-20.6) of female participants. Differences were not quite as large among participants with T2DM (Male: 37.1%, 95% CI: 23.2-53.7; Female: 36.6%, 95% CI: 23.6-51.9; Table 4.2). There were important trends when comparing newly-diagnosed, registry participants to those who participated in the cohort, which included participants who were diagnosed at least 5 years prior. Among cohort participants, 16.0% of those with T1DM and 34.1% of those with T2DM experienced food insecurity (p-value=0.01; data not shown). In contrast, food insecurity was more common among registry participants and differences by diabetes type were not as pronounced. Among registry participants, 21.7% of those with T1DM and 40.6% of those with T2DM experienced food insecurity (p-value=0.054; data not shown). The findings that food insecurity is more common among registry participants, regardless of diabetes type, and the different trends, may provide insight to the impact that chronic disease diagnosis, particularly of a child, has on the financial stasis of a household.

Given the important downstream implications, it is exceptionally important to propose effective strategies to mitigate these effects by addressing these disparities and alleviate food insecurity among YYA with diabetes. Among populations with diabetes, food insecurity is associated with poorer glycemic control(116, 228, 231, 234, 242, 293) and hospitalizations(52, 57, 197, 232, 293). However, it is important to acknowledge this finding may be a result of artifact. Food insecurity(20, 180, 294) and T2DM(118, 126)

share many correlates such as race and ethnicity and parental socioeconomic status including poverty, education, and other environmental factors(268, 269, 295) that might impact behavioral risk factors such as availability of fast food or safety for outdoor activities. In contrast, T1DM is generally associated with socioeconomic indicators such as higher income and higher levels of education(115, 120).

In this population of YYA with T1DM and T2DM, food insecurity was not significantly associated with age. Among YYA with T1DM, the proportion of younger (0-17 years old: 19.0%; 95% CI: 13.8-25.7) was slightly higher than those who were older (≥18 years: 14.4%; 95% CI: 9.0-22.2), but these differences were not statistically significant (Table 4.2). Further, the standardized food security score was similar across age groups (0-17 years old: 0.9±1.7; 18+ years old: 0.8±1.4; p-value: 0.5; data not shown). As with YYA with T1DM, in YYA with T2DM, food insecurity was experienced by similar proportions of younger (0-17 years old: 39.3%; 95% CI: 23.5-57.6) and older participants (≥18 years: 35.4%; 95% CI: 23.4-49.6; Table 4.2). Again, the average standardized food security score was not significantly different across these age groups (0-17 years old: 1.8±2.2; 18+ years old: 1.6±2.0; Table 4.2).

These findings were unexpected given well-established national data. Food insecurity is measured at the household level and the prevalence varies considerably among households based on their composition, including age of household member. Households that include children under 18 years old have a higher prevalence of food insecurity than those without any kids and the prevalence of food insecurity is lower among households with a member over the age of 65(20, 31, 296, 297). Studies examining trends specific to an individual's age seem somewhat limited and often group relatively large age ranges.

Despite these limitations, existing literature does provide further evidence to support an association with children(232, 298) and older adults(45, 232, 299) in the general population as well as populations with diabetes(40, 45, 231, 232). Notably, the prevalence of food insecurity is higher among those with diabetes for all age groups(45, 232).

However, these trends are reflective of the general population and may differ in populations with increased budgetary demands related to the management of chronic diseases, such as diabetes. In SEARCH 3, younger participants may have sufficient assets and resources(217, 300, 301) to help to navigate fluctuations in demands(51, 120). Over time, the consistent accumulation of expenses(38, 52) may force difficult decisions amongst competing costs(41, 302) when initially implemented coping strategies were no longer sufficient. Although the Affordable Care Act led to significant increases in coverage and reductions in medical costs among adults with diabetes(302), the direct and indirect costs of diabetes remain high(303).

Furthermore, participants are likely experiencing major milestones. The participants included in these analyses range from 3 to just under 30 years old, over half are 17 years and older. While the national prevalence evidence suggests that having a child in the household may increase the prevalence of food insecurity, which is likely an even greater stressor for families where that child has diabetes, transitioning to independence is likely to be, at minimum, comparable. While it is likely that many of the adult participants may have children of their own, some may be in college or are working, and many will have increased access to support and resources, which may positively impact their food security(253, 304, 305).

Interestingly, age-related trends in food insecurity differed by participant's sex. Younger (i.e., 0-17 years old) male participants more often reported food insecurity (T1DM: 0-17 years: 22.4%, 95% CI: 14.7-32.4; ≥18 years: 18.0%, 95% CI: 9.5-31.0; T2DM: 0-17 years: 46.2%, 95% CI: 23.2-70.9; ≥18 years: 31.8%, 95% CI: 16.2-52.9). However, the opposite was true among females (T1DM: 0-17 years: 15.7%, 95% CI: 9.3-25.1; ≥18 years: 11.5%, 95% CI: 5.4-22.1; T2DM: 0-17 years: 33.3%, 95% CI: 15.0-58.5; ≥18 years: 38.5%, 95% CI: 22.4-57.5; Table 4.2). This may suggest that women bear the brunt of food insecurity in adulthood.

There are some limitations to these analyses. First, the sample size was relatively small. While sufficient to detect larger trends by diabetes type (i.e., RQ1), the analyses comparing by age group (i.e., RQ2), especially when stratifying by participant's sex, may have required a larger sample size. Second, the age categorizations may have been too large or otherwise obscured potential associations. However, even when examined continuously, differences in age at time of visit were not statistically significant. Further, age classifications matched definitions traditionally used in national reports, which consistently demonstrate that households with a member under 18 years old have a higher prevalence of food insecurity compared to adult-only households(20, 31, 296, 297). Lastly, In SEARCH 3, a new sampling scheme was adopted for the cohort, which is a majority of the sample. The SEARCH 3 cohort included withal participants diagnosed with T2DM and a subset of those with T1DM, all cohort participants were diagnosed 5+ years prior. As a result, unidentified selection bias may have affected participation among those with T1DM and participation bias is inherently a concern for both groups.

In conclusion, in this cohort of youth and young adults with diabetes, almost 1 in 3 YYA with diabetes were living in a household that had some level of concern about having enough money for food and more than 1 in 5 participants (21.4%) experienced food insecurity. More than double the participants with T2DM (36.8%; 95% CI: 26.9-48.1) reported experiencing food insecurity compared to participants with T1DM (17.2%; 95% CI: 13.2-22.1), a ratio that was similar regardless of age group. Male participants report experiencing food insecurity more often than female participants, and is more common among younger male participants. Given the important downstream implications, it is exceptionally important to propose effective strategies to mitigate these effects by addressing these disparities and alleviate food insecurity among YYA with diabetes.

5.2 Specific Aim 2 (SA2)

5.2.1 Food Security and Dietary Quality

In this population of YYA with T1DM and T2DM, dietary quality was generally low (Table 4.4) and there was little evidence to support a relationship between food security and DASH dietary recommendations (Table 4.4-4.8). Although there was some evidence to suggest food security was associated with adherence to the DASH diet, most associations attenuated after adjustment (Tables 4.5-4.8).

Dietary recommendations for people with T1DM and T2DM center around monitoring carbohydrate intake(306, 307). Carbohydrates should account for about half of caloric intake, however the proportion in this population is much higher. Over 65% of this sample reported diets with carbohydrates accounting for 60% or more of daily caloric intake. Dietary guidance emphasizes intake of complex carbohydrates (e.g., fruits and vegetables) and limiting simple carbohydrates (e.g., candy and sugars). Despite this, the

average total vegetable (2.4±1.9 servings per day) and fruit (1.7±1.6 servings per day) intake was low and total intake of sweets (13.4±11.7 servings per day) was high and differed by food security status (in servings per day; FS: 12.6±11.1; FIS: 16.9±13.6; p-value: 0.03; data not shown). These trends are reflected in the DASH scores for each of these food groups, which are, on average, also low (Table 4.4).

Healthy diets should adjust consumption to reduce cardiovascular risk. For people with diabetes, monitoring dietary fat is key to maintaining a healthy weight and reducing cardiovascular risk. On average, about 20% of caloric intake among YYA in this sample was from fat (Table 4.4). Saturated fat intake was, on average, 14.03 grams per 1000 kcal, more than double the recommendation(308) and average total fat (41.81±7.25 grams per 1000 kcal) is also high in this population(309) (Table 4.4). Mean daily intake of total (in grams; FS: 67.7±31.6; FIS: 80.4±30.5; p-value: 0.02), saturated (in grams; FS: 22.8±11.1; FIS: 26.9±11.4; p-value: 0.03), and *trans* (in grams; FS: 2.2±1.3; FIS: 2.7±1.2; p-value: 0.01) fats were, on average, higher among food insecure YYA (data not shown). Limiting sodium intake is important in the context of cardiovascular risk(310), however mean sodium intake in this population was much higher than recommended (in mg per day; 2885.7±1326.8; FS: 2775.0±1279.5; FIS: 3343.7±1432.8; p-value: 0.01; data not shown). After standardizing by caloric intake, these differences were no longer statistically significant (Table 4.4). However, differences in total intake may have important implications for cardiovascular health.

The daily caloric intake reported by YYA in this population was, on average, fairly low (1680.5±731.5; Table 4.4), ranging from 369.8 to 5161.7 kcal per day (data not shown). The caloric intake for the majority, over 75%, of these YYA did not meet the

estimated energy requirement(282), including just over half of participants reporting a diet that did not meet the lowest estimated energy requirement (i.e., 1600 kcal per day).

Yet, there were statistically significant differences in caloric intake by food security status. Daily caloric intake was, on average, higher among YYA in food insecure households (FS: 1621.8±724.3; FIS: 1923.5±719.0; p-value: 0.01; Table 4.4). This despite the energy requirements estimated, on average, to be comparable (FS: 2156.0±439.2; FIS: 2165.9±389.4; p-value: 0.9; data not shown). While the accuracy of energy intake estimates when using a Food Frequency Questionnaires (FFQs) is somewhat problematic and a well-documented limitation(17, 172, 311), this may support the hypothesis that food insecurity leads to substituting higher quality foods for lower cost, energy dense options(38, 183, 312, 313).

Dietary quality was fairly low in this sample. A finding that is consistent with previous research in the SEARCH population(11, 15, 17, 281). There was no one in this sample whose diet perfectly adhered to the DASH diet. Perfect adherence to the DASH diet would include a participant whose overall score is 80, the maximum possible number of points. In this cohort, the average score is about half of that (40.1±10.1), with scores that ranged from 16.7-62.2 (data not shown). Although these differences were not statistically significant, DASH score, on average, was slightly higher among the food secure participants (40.7±10.0) compared to those who were food insecure (37.4±10.5; p-value: 0.06; Table 4.4). This is consistent with literature that has consistently demonstrated a relationship between measures of food insecurity and lower dietary quality in national samples of children(314), adolescents(315) , and adults(316, 317).

Though there were no participants who reported a diet that was completely adherent overall, there were some participants with perfect adherence for most components, which may suggest that participants are tailoring their diet to meet their personal needs and preferences. Most participants, 91.6%, reported perfect adherence to at least one component, many reporting adherence to two (27.9%) or three (28.2%), though some reported more (7.0%), and the average number of components with perfect adherence differed significantly by food security status (FS: 2.1±1.1; FIS: 1.5±1.2; p-value: 0.003). Most often, participants reported perfect adherence to fats and oils (66.4%), meats, poultry, fish, and eggs (38.5%), nuts, seeds, and legumes (34.1%), and sweets (33.6%).

Unfortunately, participants often reported diets with no adherence (i.e., a score of 0) to one or more components. About 75% of participants reported no adherence to at least one component, usually one (35.4%) or two (31.9%). Most often this included sweets (48.2%) and nuts, seeds, and legumes (40.3%). While a well-rounded diet is preferable and may lead to better long-term outcomes(11, 14, 281), these trends in adherence provide further support that participants are individualizing their diets to meet their needs in more sustainable ways.

Food security, both as a standardized score (Table 4.5) and dichotomized status (Table 4.6), was not statistically significant for most dietary outcomes when examined continuously. Those that were statistically significant in crude models attenuated after adjustment for participant's sex, age at time of clinic visit, clinic location, participation in food assistance, socioeconomic status, time since diabetes diagnosis, and diabetes type.

There were similar trends when examining the relationships between tertiles of adherence to DASH dietary recommendations and food security. High-level, compared to

low-level, adherence was not associated with either measure of food security including standardized food security score (Table 4.7) or food security status (Table 4.8) for most dietary outcomes and there were no statistically significant findings when examining mid, compared to low, level adherence categories for any dietary outcome.

Importantly, the relationship between food security and DASH component for meat, poultry, fish, and eggs fairly consistent for most analyses. For this component, higher scores are indicative of lower intake, which reflects DASH dietary guidance to limit intake of these types of foods. In crude models, both the standardized food security score (β: -0.43; 95% CI: -0.73, -0.12; p-value: 0.01; Table 4.7) and household food insecurity (β: -1.63; 95% CI: -2.89, -0.36; p-value: 0.01; Table 4.8) were statistically significant. More simply, YYA from households that were food insecure reported dietary intake associated with lower component adherence scores, meaning they reported eating more meat, poultry, fish, and eggs. However, after adjustment these relationships attenuated.

Similar associations were demonstrated in analyses exploring the association between food security and high, as compared to low, adherence to meat, poultry, fish, and eggs recommendations. Notably, the association with high-level, compared to low, adherence persisted adjustment. In this model, the standardized score (AOR: 0.74, 95%CI: 0.57, 0.98; p-value: 0.03) was statistically significant, even after adjustment for participant's sex, age, clinic location, participation in food assistance, socioeconomic status, time since diabetes diagnosis, and diabetes type (Tables 4.7).

Notably, participating in food assistance was a statistically significant predictor of lower overall DASH score in models with standardized food security score ($\beta_{assistance}$: -4.19; 95%CI: -7.25, -1.14; p-value: 0.01) and food insecurity ($\beta_{assistance}$: -4.70; 95%CI: -7.81, -

1.59; p-value: 0.003; data not shown). The association between food assistance participation and poorer dietary quality is well-documented. Previous research has consistently demonstrated this relationship between participation and poorer dietary quality, even when compared to those who qualify and do not participate. Findings are suggestive of unmeasured bias related to the poorly understood self-selection effect into program participation(318).

The similar dietary patterns, regardless of food security status, was a somewhat unexpected finding. Typically, those in food insecure households report reducing or otherwise changing their meal composition(33) and, compared to low-income food secure adults, those experiencing food insecurity generally report lower dietary quality(316, 317). More specifically, households experiencing food insecurity often report lower average intake of meat and alternatives(32, 33, 35, 38, 179), milk products(32-34), and fruits and vegetables(32-38) and higher energy density(32, 38, 39) and energy derived from carbohydrates(32, 39). Among children and adolescents, food insecurity has been associated with lower dietary quality(220, 314, 319) including lower greens and beans, seafood and plant protein, and added sugar(319), higher total energy, fat, sugar, and fiber(222), and lower total vegetable(222) and fruit consumption(34, 320). For the most part, after standardizing by caloric intake, we did not find this in the SEARCH 3 population. There were statistically significant differences in caloric intake (FS: 1621.8±724.3; FIS: 1923.5±719.0; p-value: 0.01; Table 4.4) that are supported by the literature.

Yet, in the context of diabetes and diabetes management, there are limited changes that can be made to dietary intake and many strategies typically used to navigate food insecurity may not be viable. Given the nature of diabetes and an often tightly regulated

diet, it is unlikely that there would be significant differences in many of the components without notable repercussions. As a result, it may be less likely to see households adopting other strategies when experiencing food insecurity or, perhaps, it is less likely that the YYA with diabetes will experience these dietary changes.

There are several limitations to this study. Food frequency questionnaires often underestimate intake, limited by both participants capacity for recall and the comprehensiveness of food items presented(311, 321). Yet, due to the low respondent burden and adaptability, the FFQ remains the best option to measure usual dietary patterns over time, making it the ideal tool to meet the needs of the SEARCH study. Further, participants may have a better understanding and be more aware of their eating patterns compared to other populations due to the nature of diabetes and dietary management options. Unfortunately, while this is beneficial for recall, participants nutritional knowledge may have made them more susceptible to social desirability biases, despite directions specifically indicating otherwise. SEARCH adapted the FFQ to accommodate the cognitive ability of youth, the frame of reference in the SEARCH FFQ is one week whereas typically FFQs assess usual intake in the past year. This may increase accuracy within the defined period of reference since the concept of usual intake is cognitively difficult for people regardless of age and responses likely skew towards more recent memory, regardless of framing. The SEARCH FFQ favors brevity and is shorter than other FFQs, making the list of food items less comprehensive. To accommodate this, the SEARCH FFQ incorporates ethnically diverse and culturally relevant foods specific to the populations included and estimates of reliability and validity in a similar SEARCH cohort were reasonable(172). Additionally, since participants in this cohort were diagnosed, on

average, 101.5 months (range: 59-160 months) prior to their visit, it is unlikely that made unpredictable changes to their dietary habits, as might after more recent diagnosis(17).

Another limitation is the relatively small sample size. It may be that, in populations with diabetes, associations are smaller in magnitude and potentially required more power. Another advantage of a larger sample size is that it would have allowed for stratification by diabetes type. Since there are inherent differences between T1DM and T2DM, stratifying these analyses by diabetes type may have been more appropriate than adjustment. Food insecurity is more common (Table 4.3) and DASH component scores were generally lower among YYA with T2DM compared to those with T1DM (data not shown). Specifically of concern, were the statistically significant differences in overall DASH score (T1DM: 41.0±10.0; T2DM: 35.5±9.7; p-value: 0.002), as well as component scores for dairy (T1DM: 5.6±3.0; T2DM: 4.0±2.9; p-value: 0.002), including low fat dairy (T1DM: 2.5±2.0; T2DM: 1.8±1.9; p-value: 0.03), and meats (T1DM: 6.7±3.9; T2DM: 5.2±3.8; p-value: 0.03; data not shown). Unfortunately, the sample size was not sufficiently powered for stratified analyses.

Another consideration is the wide age range represented in this cohort. This cohort included children, who are often thought to be insulated against the effects of food insecurity(31). However, there is some evidence to suggest that children's diets also change to some extent(34, 220-222, 322). While including children in these analyses may have obscured some associations between food security and dietary outcomes, the results presented were consistent with respect to the existing literature that food insecure households frequently identify increasing the intake of energy dense foods that are often more filling as budgeting strategies(33).

Lastly, these findings may be attributable to selection bias resulting from the sampling scheme or nonresponse. This analysis is based on the SEARCH 3 cohort, which included a structured sampling scheme inviting only a subset of the cohort with T1DM to participate. While participants with T2DM are likely comparable to the larger population with youth-onset T2DM, unidentified selection bias may affect the generalizability of these results with respect to T1DM. However, in the context of youth-onset diabetes, the association between food insecurity and dietary quality is less likely to be affected by these factors. More concerning is the potential for nonresponse bias. This cohort includes long-time participants, those who were able to participate may be more financially stable and less transient, and among those, those who choose to participate may be more aware or concerned with their health. Inherent in this is an underestimate of YYA experiencing food insecurity and that dietary quality may be, in fact, poorer than has been presented.

In conclusion, in this population of YYA with T1DM and T2DM, there is limited support for a relationship between food security and dietary quality. Though there were no participants who reported a diet that was completely adherent overall, most participants reported perfect adherence to at least one of the DASH components, which may suggest that participants are tailoring their diet to meet their personal needs and preferences. While food security was not a statistically significant predictor of overall DASH score or most dietary outcomes, the results suggest a relationship with the meat, poultry, fish, and eggs component, particularly when categorized into adherence tertiles.

5.2.2 Food Security and Electronic Media Use

In this population of YYA with T1DM and T2DM, there was no statistically significant relationship between any of the electronic media outcomes and food security

measures, both as a standardized score (Table 4.11 & 4.13) and dichotomized status (Table 4.12 & 4.13). This included crude models and those adjusted for age at the time of visit, site visited, diabetes type, socioeconomic status, and participant's sex. Though not statistically significant, the point estimates of some results did suggest the possibility of an underlying relationship that may simply have fallen short of statistical significance due to the small sample. Specifically, the relationship between food insecurity and high-level electronic media use outcomes: television use (≥2 hour daily; AOR: 1.57; 95% CI: 0.73-3.35) and leisure-time computer use (≥2 hour daily; AOR: 0.53; 95% CI: 0.25-1.13), respectively (Table 4.13).

In the US, most people engage in watching television daily, including 79.5% who watch a daily average of 2.6 hours during weekdays and 80.8% that averaging 3.3 hours during weekends, far surpassing other leisure activities in 2013-17. For example, the next most common leisure activity was socializing or communicating on weekends, which 44.1% participated in for an average of 1.1 hours daily(323). In the US, states in the Southeast report the highest amount of television viewing. The daily average in South Carolina was 3.1 hours compared to 2.4 hours in Washington(324).

In this cohort, participants reported, on average, 3.7 (±2.3) hours of daily electronic media use. Average time spent watching television was 2.1 (±1.4) hours daily compared to 1.6 (±1.5) hours daily of average leisure time computer use (Table 4.10). Leisure-time computer use was far less common, 64% reported participating less than 2 hours daily (Table 4.10). Over half (53%) of the cohort reported an average daily use of an hour or less, including 20% who reported that they did not use the computer for leisure activity

(data not shown). These patterns in leisure-time computer use seem to suggest that it may be a unique subset of the cohort who choose to participate in this activity frequently.

Contextualizing the question is important given the rate at which technology continues to expand. As a results, it is important to consider that these data were collected during 2013-15 when interpreting the implications of these findings. Although the vast majority of US households had internet access (77.3%) and a computer (86.5%), including 78.3% with a desktop or laptops and 74.2% with other handheld devices (e.g., smart phone), there were notable differences in access and utilization by geographical region. Specifically, while 83.9% of households in Washington had access to broadband internet, in South Carolina 69.9% had broadband internet and there were unique differences in access to the internet and handheld ownership in that region(325). Given the shifting technological landscape, it is also difficult to discern what constituted computer use outside of gaming, which was specified in the question, and, for that matter, television watching.

Although neither measure of food security was a predictor of any electronic media outcomes (Tables 4.11-4.13), age and socioeconomic status were statistically significant predictors when modeling daily and weekday electronic media use (data not shown). Since electronic media use is a composite of television and computer use, but none of the covariates were significant when modeling computer use, it is likely that these associations were largely driven by associations with television behaviors. In these analyses, age was associated higher reported engagement, whereas high socioeconomic status was associated with lower engagement compared to low socioeconomic status. In analyses modeling television use, clinic location (i.e., South Carolina compared to Washington) was also statistically significant and associated with higher reported television use (data not shown).

When modeling weekend television use, age was the only statistically significant predictor suggesting that weekend behaviors may be more universal, at least with respect to the characteristics included as covariates.

National trends support these findings that behaviors related to electronic media engagement differ by age(323, 324), socioeconomic status(323), and region(324). People in older age groups, on average, reported spending more time watching television and, more generally, on sedentary behaviors (e.g., reading, relaxing and thinking) whereas they report spending less time engaging in active behaviors (e.g., sports, exercise, and recreation or other leisure and sports including travel)(323, 324). In contrast, those that report higher income and or education report more time, on average, spent engaging in physically active activities and less on sedentary activities, aside from reading, which increases with both income and education(323). Notably, playing games and computer use for leisure is an exception to these trends, which is consistent with findings in this population. Time spent playing games or using the computer is highest among youngest and oldest age groups, mid-to-low income earners, and those with an associate's degree or some college education(323).

This study had several potential limitations. First, electronic media use was assessed by self-report. Studies assessing the validity of similar measures consistently demonstrate that self-report measures of electronic media use overestimate, comparatively, in a variety of contexts(326-330) and may differ depending on the content being assessed(327). However, poor validity is a larger issue for most self-report assessment tools and an issue that most research, especially in the context of large-scale epidemiologic studies, constantly grapple with. Despite this, the reliability has been shown to be fairly

high(328), which is further demonstrated by the consistency of these results with national estimates(323). Second, the questions around electronic media use, as well as physical activity, made it difficult to discern the context in which these activities are occurring. Particularly electronic media use often occurs in the background while other activities are ongoing(323, 324). As a result, the motivation and logic underpinning the research question needs to be carefully considered. In this case, sedentary behaviors were of interest and, given television may cooccur with physical activity, results need to be interpreted carefully.

Another limitation was relatively small sample size. The point estimates of some results did suggest the possibility of an underlying relationship that may have required a larger sample size for statistical testing. Specifically, the relationship between food insecurity and high-level electronic media use outcomes: television use (≥2 hour daily; AOR: 1.57; 95% CI: 0.73-3.35) and leisure-time computer use (≥2 hour daily; AOR: 0.53; 95% CI: 0.25-1.13), respectively (Table 4.13). In addition, a larger size would have allowed for stratification by diabetes type rather than covariate adjustment, which likely would have been appropriate. Although leisure computer use did not significantly differ by diabetes type (T1DM: 1.5±1.5; T2DM: 1.9±1.5; p-value: 0.1), television use did (T1DM: 2.0±1.3; T2DM: 2.8±1.5; p-value: 0.0004; data not shown) and a larger sample size would have allowed for further investigation into these differences.

Another consideration is the potential for selection effects. This analysis is based on the SEARCH 3 cohort, which included a structured sampling scheme inviting only a subset of the cohort diagnosed with T1DM to participate. While participants with T2DM are likely comparable to the larger population with youth-onset T2DM, unidentified selection bias may affect the generalizability among populations with T1DM. However,

the association between food insecurity and electronic media use is unlikely affected by these factors. Similarly, there are a number of factors that may have impacted nonresponse among this cohort after five or more years. Given the length of participation, those who were able to participate may be more financially stable and less transient, and among those, those who choose to participate may be more aware or concerned with their health. However, it would be impossible to predict access and use of electronic media in participants who did not respond.

There are several recommendations for future research that derive from the above-mentioned limitations. Better defining constructs in relation to the evolving technology is an important consideration for future assessments. Television is changing and now includes streaming services. While most streaming occurs on devices through the television, much does not. It is unclear whether participants included streaming if it occurred on other devices (e.g., tablet or smartphone) or how a participant would attribute streaming television shows if using their computer (e.g., laptop). This issue extends further in the new technological landscape (e.g., youtube) and how participants define television, whether a television show (i.e., excluding movies) or what is viewed on a television set. Computer use is similarly evolving. Whereas leisure computer use once included social media access and online shopping, the use of computers has shifted. More recently, computer use more likely includes streaming television or gaming. Given that gaming is heavily dependent on the platform preference of the user, not including questions specific to other platforms (e.g., Playstation, smartphones) is a major limitation.

There are societal and cultural considerations to take into account when considering future research in this domain. Despite the average number of television sets in homes

decreasing, they are being replaced with other devices(331), further embedding the act of watching television into our culture. Many people interact with technology casually, e.g., while doing other things(323, 324). Television is often the center of social events (e.g., sports) and many people watch television even while being physically active. Even when not actively engaging with television, many people passively engage, leaving the television on for background noise. Assuming smart phone are extensions of computer use, similar principles theoretically apply as well.

In this population of YYA with T1DM and T2DM, the relationship between food insecurity and electronic media use is unclear. It is important to better understand the relationship with physical activity and sedentary behaviors, including electronic media use. This is especially true in the context of diabetes, since reducing sedentary behaviors and increasing physical activity is tied to better health outcomes and may mitigate some metabolic outcomes. Future research should work to better elucidate this relationship.

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