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Household Food Insecurity and Associations with Hemoglobin A_{1c} and Acute Diabetes-Related Complications in Youth and Young Adults with Type 1 Diabetes: The SEARCH for Diabetes in Youth study

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Abstract

Aims: To examine, among youth and young adults (YYA) with type 1 diabetes (T1D), the association of household food insecurity (HFI) with: 1) HbA_{1c} and 2) episodes of diabetic ketoacidosis (DKA) and severe hypoglycemia.

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Duality of Interest. No potential conflicts of interest relevant to this article.

Methods: HFI was assessed using the U.S. Household Food Security Survey Module in SEARCH for Diabetes in Youth participants with T1D between 2016–2019. Linear and logistic regression models adjusted for age, diabetes duration, sex, race, ethnicity, clinic site, parent/participant education, household income, health insurance, and diabetes technology use.

Results: Of 1830 participants (mean age 20.8±5.0 years, 70.0% non-Hispanic White), HbA_{1c} was collected for 1060 individuals (mean HbA1c 9.2%±2.0%). The prevalence of HFI was 16.4%. In the past 12 months, 18.2% and 9.9% reported an episode of DKA or severe hypoglycemia, respectively. Compared to participants who were food secure, HFI was associated with a 0.33% (95% CI 0.003, 0.657) higher HbA_{1c} level. Those with HFI had 1.58 (95% CI 1.13, 2.21) times the adjusted odds of an episode of DKA and 1.53 (95% CI 0.99, 2.37) times the adjusted odds of an episode of severe hypoglycemia as those without HFI.

Conclusions: HFI is associated with higher HbA_{1c} levels and increased odds of DKA in YYA with T1D.

Keywords

food insecurity; type 1 diabetes; youth; young adults; social determinants of health

1. Introduction

Household food insecurity (HFI) continues to be a significant public health challenge in the United States (US) with more than 1 in 10 households and 1 in 8 households with children identified to be food insecure in 2021.[1] The SEARCH for Diabetes in Youth (SEARCH) study recently reported that youth and young adults (YYA) with type 1 diabetes are even more disadvantaged, as almost 1 in 5 (18%) YYA with type 1 diabetes are food insecure.[2] Given that diabetes management requires careful alignment of medication and dietary intake, YYA with type 1 diabetes face additional health challenges secondary to uncertainty in the availability of food stemming from HFI.

Defined by the American Diabetes Association as the unreliable availability of nutritious food and the inability to consistently obtain food without resorting to socially unacceptable practices,[3,4] HFI can negatively influence glycemic control through its potential impact on nutrition therapy, physical activity, and diabetes self-management. Thus, HFI represents a potentially modifiable risk factor for adverse diabetes outcomes among socially disadvantaged populations. Pilot work carried out through the SEARCH Food Security study demonstrated that YYA with type 1 diabetes who lived in food insecure households had 2.4 higher adjusted odds of having a hemoglobin A_{1c} (HbA_{1c}) >9.0% (>75 mmol/mol) compared to those living in a food secure household.[5] Furthermore, persons with marginal food security, who technically are classified as food secure on the U.S. Household Food Security Survey Module (HFSSM), had an elevated risk of higher HbA_{1c}. This pilot study, however, enrolled participants in Washington and South Carolina only, which limits its generalizability. Thus, these findings require confirmation in a larger and more diverse sample, as these findings would have strong implications for practice guidelines, including more nuanced recommendations for diabetes care depending on level of HFI and HbA_{1c}.

Studies examining the impact of HFI in adults with chronic disease have found that food-insecure adults with chronic disease must often choose between paying for health care and for food, leading to suboptimal adherence to medications, prolonged periods of fasting, and increased health care utilization.[6,7] Similarly, in older adults with type 2 diabetes, HFI has been found to be associated with more episodes of severe hypoglycemia and emergency department visits and hospitalizations.[8–11] In YYA with type 2 diabetes, food insecure YYA have been reported to have higher odds of diabetic ketoacidosis (DKA) compared to YYA living in food secure households.[12] To our knowledge, no population-based studies have examined the association between HFI and rates of DKA and severe hypoglycemia in YYA with type 1 diabetes. We sought to examine the association of HFI with 1) glycemic control, 2) episodes of DKA, and 3) episodes of severe hypoglycemia among a large cohort of YYA with type 1 diabetes from the SEARCH for Diabetes in Youth study.

2. Materials and Methods

2.1 Study Population

We utilized data from SEARCH, a multicenter observational study of provider-diagnosed diabetes in youth diagnosed before the age of 20 years.[13] SEARCH includes 5 centers located in California, Colorado (including selected American Indian reservations in Arizona and New Mexico), Ohio, South Carolina, and Washington.

This study included cohort participants from the fourth phase of the SEARCH study (SEARCH 4) with type 1 diabetes. Briefly, SEARCH Phase 1 identified cases that were prevalent in 2001 and incident cases occurring between 2002 and 2005. SEARCH Phase 2 included surveillance efforts for incident diabetes cases in 2006 and 2008; and additionally initiated follow-up of enrolled Phase 1 incident cases 12-, 24- and 60-month after their initial visits. SEARCH Phase 3 ascertained incident cases between 2010 and 2015.

In SEARCH 3, a SEARCH cohort was created by means of recruiting participants from Phases 1 and 2 to another in-person visit if they (1) had a diagnosis date between 2002 and 2005, 2006, or 2008, (2) completed a baseline in-person visit, and (3) had at least 5 years of diabetes duration at the time of the visit. In SEARCH 4, all SEARCH cohort participants aged >10 years (plus those cases with an initial in-person visit in SEARCH 3 and a diagnosis date between 2011 and 2015) were eligible for another follow-up and operationally split into a group invited to another study visit between 2015 and 2019 (research visit participants), and those who were only invited to complete surveys (survey only participants). Those invited to SEARCH 4 in-person visits included all those with type 2 diabetes, all nonwhites and a random sample of non-Hispanic whites with type 1 diabetes. The remaining random sample of non-Hispanic white participants constituted the survey only group. Over 75% of research visit eligible participants completed SEARCH 4 study activities, while approximately 67% of survey only eligible participants participated in SEARCH 4 study activities.

The study was approved by and followed procedures in accordance with the ethical standards of the respective local Institutional Review Boards. Before data collection commenced, parents/guardians of participants under age 18 provided written informed

consent while participants ages 8 −17 years provided assent. All participants 18 years or older provided written informed consent.

2.2 Assessment of Household Food Insecurity

HFI was assessed using the 18-item U.S. Household Food Security Survey Module (HFSSM).[4] This instrument measures HFI over the previous 12 months and was developed to estimate the prevalence of HFI and monitor changes over time among groups of households in the U.S. HFSSM items reflect a range of severity of food insecurity experiences, including feelings of uncertainty about having enough food or the right quality of food and ensuing behaviors, such as cutting the size of a meal. The first 10 questions pertain to all households (with or without children) and the last 8 questions are only asked of households with children ages 0–17. Thus, possible responses range from 0–10 affirmations for households without children and 0–18 affirmations for households with children (higher scores indicate increased HFI).

The HFSSM was completed by parents/guardians of minor participants or participants 18 years of age or older. We used two types of scores derived from the HFSSM. First, the responses to the HFSSM were converted into a continuous raw score, with higher values indicating more severe HFI. The USDA provides an equivalent standardized scale (range 0–9.3) to allow for direct comparisons between households with and without children.[4] Given that not all participant households included children, a continuous scaled score was also calculated for participants for regression analyses. Additionally, the HFSSM results were classified into four categories: high food security (zero affirmations), marginal (1–2 affirmations), low (3–7 affirmations among households with children, 3–5 among households without children), or very low food security (≥8 affirmations in households with children, ≥ 6 affirmations in households without children).[1,4] When comparing food secure versus food insecure households, households were classified as food insecure if the respondent affirmed ≥3 food insecure conditions or behaviors.

2.3 Assessment of Glycemic Control and Acute Complications of Diabetes

SEARCH study visits included questionnaire administration. For research visit participants, this included collection of physical measurements and a blood sample. Average glucose levels were assessed based on a participant's HbA_{1c} level, which was measured from a sample of whole blood obtained from participants during an in-person visit.

Information about acute diabetes-related complications was collected via survey. To assess DKA episodes, participants were asked, "In the last 12 months, have you (has your child) had diabetic ketoacidosis (often called DKA, frequently with high blood sugar, vomiting and shortness of breath)?" To collect information about severe hypoglycemia, participants were queried, "In the last 12 months, have you (has your child) had any severe hypoglycemia, that is, very low blood sugar that required you to get help?" Response categories for both questions were "Yes", "No", and "Do not know." For the analysis, "Do not know" answers were set to missing and excluded from the analysis.

Inclusion of Covariates—We collected information about age, sex, diabetes duration, insulin pump use, and continuous glucose monitoring (CGM) use from participants. To assess household income, participants were presented with annual income ranges. Household income was categorized as <$25,000, $25,000-$49,999, $50,000-$74,999, and ≥$75,000 with the lower income cut-off closely approximating to the U.S. Federal Poverty line for a family of 4 in 2019. Current health insurance was assessed by asking about the type of health insurance or health care plan, which were grouped into the following categories: Private, Medicaid/Medicare, Other, None. Other categorical variables included race (Asian American/Pacific Islander, Hispanic, Native American, Non-Hispanic Black, Non-Hispanic White, Other), participant or parental education (less than high school graduate, high school graduate, some college or associate's degree, bachelor's degree or more), and SEARCH clinic site (South Carolina, Colorado, Ohio, California, Washington). For participants with missing information on household income, parental education, or health insurance status at SEARCH Phase 4, we first substituted the value from the most recently available timepoint from the SEARCH study.[12] If missing values persisted for relevant demographic characteristics, the individual was excluded from the analysis.

2.4 Study sample and statistical analysis—Youth and young adults were defined as an individual between 10 to 35 years of age. SEARCH 4 Cohort survey only and research visit YYA participants who completed the HFSSM were included in the study sample (n=1,830). All participants were asked to complete survey questions related to acute-diabetes related complications over the past 12 months. HbA_{1c} measurements were available only for the planned subsample of research visit participants who completed in-person study visits (n=1,060).

The relationship between HFI and HbA_{1c} was assessed using linear regression. Given that pilot work demonstrated a potential nonlinear relationship between HFI and HbA_{1c},[5] we also conducted a sensitivity analysis including a HFI-squared term in the linear regression to examine whether the relationship between HFI and HbA_{1c} was linear or nonlinear. Logistic regression was used to assess the association between HFI and experiencing DKA or severe hypoglycemia. All models were adjusted for the participant's age, diabetes duration, sex, race/ethnicity, SEARCH clinic site, parent education, participant education, household income, health insurance type, insulin pump use, and CGM use.

3. Results

The overall prevalence of HFI in YYA with type 1 diabetes was 16.4%, with 8.6% reporting living in households with low food security and 7.8% reporting very low food security. Additionally, 11.7% were identified as marginally food secure. The mean age for the sample was 20.8 ± 5.0 years (Table 1A). Most participants were female (52.1%), Non-Hispanic White (70.0%), and had private insurance (75.4%). Approximately 18% of the sample reported a household income less than $25,000 per year with an additional 21% reporting a household income $25,000 to $50,000.

The mean HbA_{1c} for YYA in this study was 9.2% ± 2.0% SD (77 mmol/mol ± 22 mmol/mol SD; Table 1B). In the past 12 months, 18.2% reported experiencing DKA and 9.9% reported

severe hypoglycemia. Of participants reporting an acute diabetes-related complication, 2.4% experienced both a DKA and severe hypoglycemia episode in the past 12 months.

YYA who were food insecure had a HbA_{1c} that was 0.33% (95% CI: 0.003–0.657) higher than those who were food secure when adjusting for age, sex, race, participant education, parental education, income, health insurance, study site, insulin pump use, CGM use, and diabetes duration. When evaluated as a continuous variable, we observed a positive linear relationship between HFSSM scaled score and HbA_{1c} (Figure 1). In the linear regression analysis, a 1-point higher HFSSM scaled score was associated with a 0.12% (95% CI: 0.05–0.18) higher HbA_{1c}.

For YYA that had HFI, the odds of experiencing DKA was 1.58 (95% CI: 1.13–2.21) times the odds of experiencing DKA for those without HFI after adjusting for all covariates (Table 2). When using 4 categories of HFI, the adjusted odds of experiencing DKA was the highest for YYA reporting very low food security (OR 1.87, 95% CI: 1.19–2.92), similarly elevated but not statistically significant for the low food security group (OR 1.51, 95% CI: 0.96–2.40), but much weaker in the marginal food security group (OR 1.19, 95% CI: 0.78–1.81). With respect to severe hypoglycemia, while the odds of experiencing severe hypoglycemia among the food insecure YYA compared to those who were food secure were higher, this finding did not reach statistical significance after adjusting for covariates (OR 1.53, 95% CI: 0.99–2.37).

4. Conclusions

Data from this large multicenter study demonstrates that HFI is associated with higher HbA_{1c} levels and higher likelihood of episodes of DKA in US YYA with type 1 diabetes. That HFI is associated with higher HbA_{1c} levels is consistent with two smaller studies examining food insecurity and its association with glucose levels in U.S. and Canadian YYA with type 1 diabetes.[5,14] Unlike the Mendoza et al. study, however, we did not identify an inverted U-shaped non-linear relationship of HFI with HbA_{1c}.[5] Instead, in our larger sample of YYA with type 1 diabetes, we found a positive linear relationship between the two variables such that as higher food insecurity was associated with higher HbA_{1c}. In addition, the odds of DKA were higher for food insecure YYA as compared to YYA from food secure households.

These findings extend our understanding of food insecurity among YYA with type 1 diabetes, which is an understudied population with respect to HFI. Several mechanisms have been proposed through which HFI may influence glucose levels, including through behavioral, mental health, and nutrition paths.[15] In type 1 diabetes, a condition that is dependent on insulin administration and glucose monitoring throughout the day to meet glycemic targets, perhaps the most influential mechanism is on diabetes self-management behaviors. Our finding that YYA who are food insecure have a HbA_{1c} that was 0.33% higher than those who were food secure provides additional support to the hypothesis that HFI affects health in YYA with type 1 diabetes and may divert resources away from reliable insulin administration and glucose monitoring. This study's findings are in contrast to a recently published study examining HFI in YYA with type 2 diabetes.[12] In a smaller

sample from the SEARCH study, Reid et al. did not observe an association between HFI and glycemic control in YYA with type 2 diabetes. Our results are, however, consistent with what cross-sectional studies in the adult literature have reported for type 1 and type 2 diabetes,[8,11] including a longitudinal study in adults with diabetes that demonstrated food insecurity was associated with a 0.6% higher HbA_{1c}.[16]

We found that every 1-point higher scaled HFSSM score was associated with a 0.12% higher HbA_{1c}. YYA with type 1 diabetes experiencing increasing severity of HFI may be forced to balance the costs associated with obtaining diabetes medications and supplies with maintaining adequate and nutritious food. As a result, food insecure individuals and their families may compromise on one or both aspects to reduce expenses.[17,18] These compromises also often necessitate a shift in dietary intake in YYA as poorer nutritional intake has been shown to be associated with food insecurity.[19] Changes in intake from relatively expensive fruits and vegetables and toward foods that are relatively less expensive but lower nutritional value, is also likely to contribute to higher HbA_{1c} levels.[20]

The demands for using finite household resources to meet competing needs are only magnified in an era of rapidly rising insulin prices[21] and when cost of living, including food-related costs, are also at record levels. At its most extreme, food insecure YYA may omit insulin administration altogether. We found that the odds of experiencing DKA was 1.64 times the odds of experiencing DKA for those without HFI after adjusting for all covariates, which could be explained by insulin omission due to finite household resources. Reid et al. similarly reported that food insecure YYA with type 2 diabetes had 3.08 times the odds of experiencing DKA than YYA who lived in food secure households.[12] The relationship between HFI and underutilization of medical care is well documented,[6,7,17] with evidence that adults experiencing food insecurity are more likely than their food-secure counterparts to delay or forgo medical care because of cost concerns.[22] The inability to afford to see a diabetes provider or fill prescriptions presents another potential challenge for food insecure YYA given the requirement to have active insulin prescriptions to support reliable daily insulin administration, increasing the risk for insulin omission.

Previous studies in adults with diabetes have reported food insecurity is a risk factor for clinically significant hypoglycemia.[10,23] We also observed higher odds of severe hypoglycemia in food insecure YYA, albeit this did not reach the threshold of statistical significance (1.53, 95% CI: 0.99–2.37) in our sample. The American Diabetes Association recommends that glycemic targets be tailored to the individual patients to keep them safe and to avoid significant hypoglycemia.[24] Thus, diabetes providers may relax glycemic targets when patients encounter severe hypoglycemic episodes, which may represent an additional mechanism by which HFI leads to higher average glucose levels. Food insecurity is frequently a transient and cyclic phenomenon and thus, the co-existence of significant hypoglycemia in the setting of hyperglycemia in food insecure YYA can be explained by periods of adequate food supplies alternating with inadequate supplies during the year. Given that the HFSSM queries whether the food security-related experience or behavior ever occurred in the past 12 months, more work should be done to characterize the frequency and duration of the food insecurity experience for YYA with type 1 diabetes within that 12-month window.

This study has some limitations. First, given the cross-sectional nature of the analysis, the direction of the proposed mechanistic paths cannot be inferred. Second, the time frame of the food insecurity questions is wider than that of the HbA_{1c} measurement. Thus, it is possible that HbA_{1c} measurements do not reflect concurrent food insecurity experiences. Third, our study may be impacted by recall bias since HFI, DKA episodes, and severe hypoglycemia events were self-reported. Finally, we were unable to assess emotional distress related to diabetes as a potential mechanism for reduced capability for diabetes self-management, as this may be worsened due to HFI and interfere with a patient's ability to manage their diabetes. These limitations, however, are balanced by several strengths. Strengths of the present study include its large sample size, a study population drawn from what is the largest multiethnic population-based registry of individuals with youth-onset diabetes in the U.S. with demographic and clinical characteristics similar to those of the overall U.S. population, and the use of the full 18-item HFSSM, the U.S. reference measure for HFI.

This study underscores the importance of assessing HFI in clinical settings, so that diabetes care teams can identify patients who may have challenges with following certain prescribed treatments due to the competing demands exacted by HFI and who are at higher risk for acute diabetes-related complications.[3] The Hunger Vital Sign is a validated two-item food insecurity screening instrument that has been shown to have 97% sensitivity when compared to the reference HFSSM,[25] and thus can be more easily implemented in the clinical setting. A global tool that can be used to evaluate the severity of food insecurity at the household or individual level and allows for comparison between countries is the Food Insecurity Experience Scale.[26] Regardless of the prevalence of food insecurity, local or national programs that identify food-insecure patients should be implemented in the context of institutional support for linking patients to more reliable food assistance programs and resources.[27]

Our work has important public health implications because of the substantial morbidity and mortality associated with HFI, as well as suboptimal glycemic control in diabetes. The high prevalence of HFI in the U.S. documented in this study, and its association with worse glycemic control and potentially preventable episodes of DKA, highlight the need for further investigation on the most effective ways of eliminating food insecurity among YYA with type 1 diabetes. This is particularly relevant for low and middle-income countries where food insecurity prevalence is higher than in the U.S.[28] Altogether, our findings suggest that policies and programs to identify and alleviate HFI among YYA with type 1 diabetes are urgently needed and may improve their glucose levels and reduce health care utilization for potentially preventable acute diabetes-related complications.

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SEARCH 4

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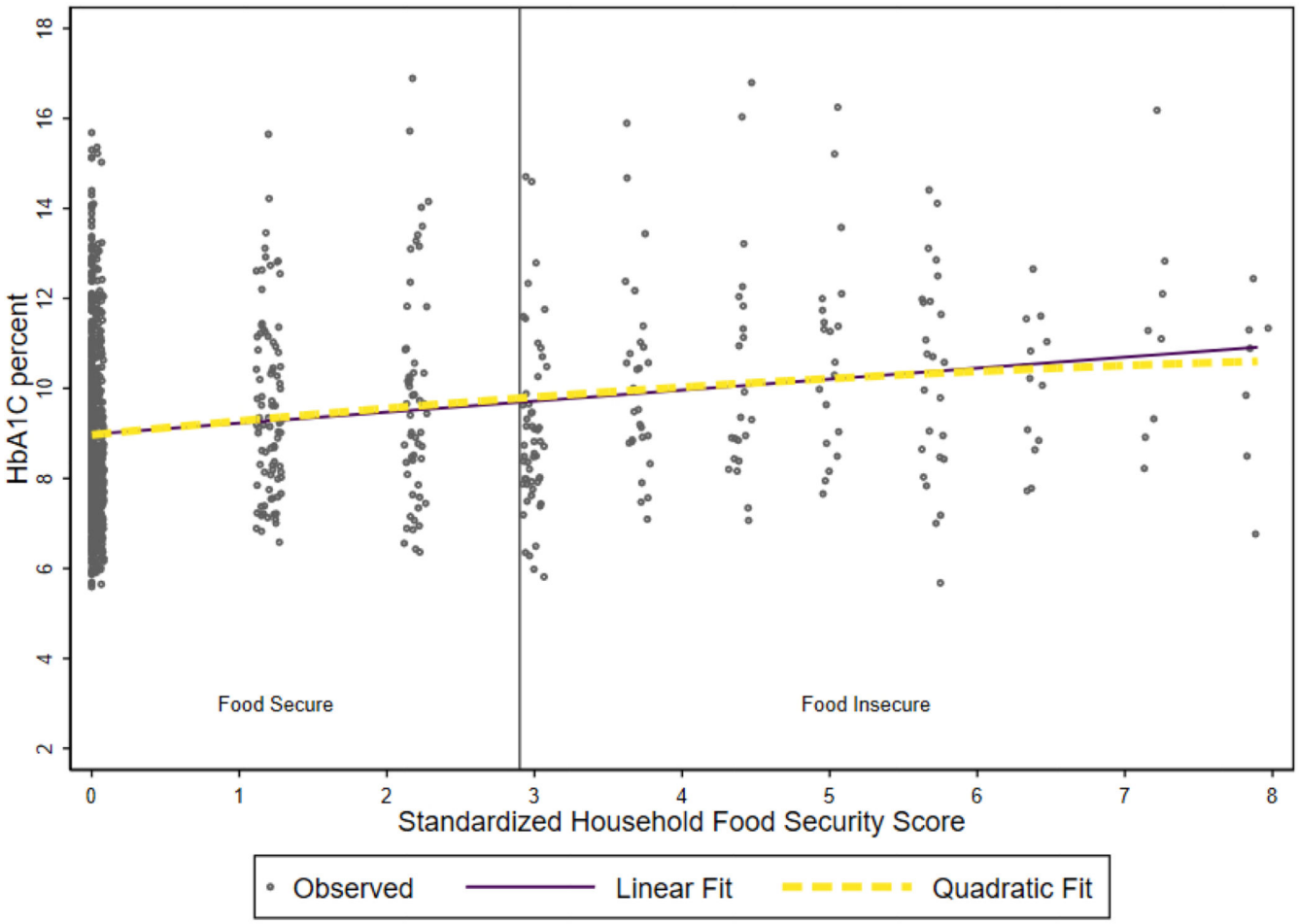

FIGURE 1.

Relationship Between Standardized Household Food Security Survey Module Score and HbA_{1c} by Food Security Status.

TABLE 1A.

Participant and Household Characteristics in Youth and Young Adults with Diabetes in the SEARCH 4 Cohort Study by Food Security Status

		Food Secure (n=1,530)		Food Insecure (n=300)	
Participant Characteristics	**Overall (n=1830)**	**High food security (n=1,315)**	**Marginal food security (n=215)**	**Low food security (n=157)**	**Very low food security (n=143)**
Age (yrs), mean (sd)	20.8 (5.0)	20.6 (5.0)	21.6 (5.0)	21.2 (4.8)	21.9 (4.8)
10–17, n (%)	556 (30.4)	428 (32.5)	52 (24.2)	42 (26.7)	34 (23.8)
18–25, n (%)	974 (53.2)	690 (52.5)	120 (55.8)	85 (54.1)	79 (55.2)
26–35, n (%)	300 (16.4)	197 (15.0)	43 (20.0)	30 (19.1)	30 (21.0)
Sex					
Female, n (%)	954 (52.1)	661 (50.3)	124 (57.7)	78 (49.7)	91 (63.6)
Male, n (%)	876 (47.9)	654 (49.7)	91 (42.3)	79 (50.3)	52 (36.4)
Race/Ethnicity					
Asian American/Pacific Islander, n (%)	40 (2.2)	30 (2.3)	5 (2.3)	2 (1.3)	3 (2.1)
Hispanic, n (%)	263 (14.4)	186 (14.1)	42 (19.5)	20 (12.7)	15 (10.5)
Native American, n (%)	11 (0.6)	6 (0.5)	2 (0.9)	3 (1.9)	
Non-Hispanic Black, n (%)	231 (12.6)	126 (9.6)	37 (17.2)	35 (22.3)	33 (23.1)
Non-Hispanic White, n (%)	1280 (70.0)	963 (73.2)	129 (60.0)	97 (61.8)	91 (63.6)
Other, n (%)	4 (0.2)	3 (0.2)			1 (0.7)
Unknown, n (%)	1 (0.1)	1 (0.1)			
Household income					
Less than $25,000, n (%)	327 (17.8)	156 (11.9)	59 (27.4)	48 (30.6)	64 (44.8)
$25,000 – 49,999, n (%)	384 (21.0)	221 (16.8)	71 (33.0)	58 (36.9)	34 (23.8)
$50,000 – 74,999, n (%)	291 (15.9)	204 (15.5)	31 (14.4)	29 (18.5)	27 (18.9)
$75,000 or greater, n (%)	715 (39.0)	653 (49.7)	36 (16.7)	15 (9.6)	11 (7.7)
Missing, n (%)	113 (6.2)	81 (6.2)	18 (8.4)	7 (4.5)	7 (4.9)
Parental education					
Less than high school graduate, n (%)	84 (4.6)	48 (3.7)	17 (7.9)	12 (7.6)	7 (4.9)
High school graduate, n (%)	257 (14.0)	139 (10.6)	50 (23.3)	33 (21.0)	35 (24.5)
Some college or Associate's, n (%)	515 (28.1)	338 (25.7)	67 (31.2)	54 (34.4)	56 (39.2)
Bachelor's or higher, n (%)	972 (53.1)	789 (60.0)	81 (37.7)	58 (36.9)	44 (30.8)
Missing, n (%)	2 (0.1)	1 (0.1)			1 (0.1)
Health Insurance					
None, n (%)	64 (3.5)	34 (2.6)	10 (4.7)	10 (6.4)	10 (7.0)
Other, n (%)	100 (5.5)	60 (4.6)	23 (10.7)	8 (5.1)	9 (6.3)
Medicaid/Medicare, n (%)	286 (15.6)	146 (11.1)	52 (24.2)	41 (26.1)	47 (32.9)
Private, n (%)	1380 (75.4)	1075 (81.8)	130 (60.5)	98 (62.4)	77 (53.9)

		Food Secure (n=1,530)		Food Insecure (n=300)	
Participant Characteristics	**Overall (n=1830)**	**High food security (n=1,315)**	**Marginal food security (n=215)**	**Low food security (n=157)**	**Very low food security (n=143)**
Diabetes duration, yrs. Mean (sd)	11.2 (3.1)	11.1 (3.1)	11.4 (3.1)	11.5 (2.9)	11.4 (3.3)
Insulin pump use					
Yes, n (%)	1056 (57.7)	844 (64.2)	81 (37.7)	72 (45.9)	59 (41.3)
No, n (%)	746 (40.8)	456 (34.7)	128 (59.5)	80 (51.0)	82 (57.3)
Missing, n (%)	28 (1.5)	15 (1.1)	6 (2.8)	5 (3.1)	2 (1.4)
CGM use					
Yes, n (%)	652 (35.6)	530 (40.3)	56 (26.1)	38 (24.2)	28 (19.6)
No, n (%)	1150 (62.8)	769 (58.5)	154 (71.6)	115 (73.2)	112 (78.3)
Missing, n (%)	28 (1.5)	16 (1.2)	5 (2.3)	4 (2.6)	3 (2.1)
Diabetic ketoacidosis episode					
Yes, n (%)	333 (18.2)	203 (15.4)	44 (20.5)	42 (26.8)	44 (30.8)
No, n (%)	1453 (79.4)	1091 (83.0)	161 (74.9)	108 (68.8)	93 (65.0)
Missing, n (%)	44 (2.4)	21 (1.6)	10 (4.7)	7 (4.5)	6 (4.2)
Severe hypoglycemia episode					
Yes, n (%)	181 (9.9)	122 (9.3)	15 (7.0)	25 (15.9)	19 (13.3)
No, n (%)	1638 (89.5)	1186 (90.2)	199 (92.6)	130 (82.8)	123 (86.0)
Missing, n (%)	11 (0.6)	7 (0.5)	1 (0.5)	2 (1.3)	1 (0.7)
Both DKA and severe hypoglycemia					
Yes, n (%)	45 (2.5)	23 (1.8)	3 (1.4)	14 (8.9)	5 (3.5)
No, n (%)	1733 (94.7)	1266 (96.2)	201 (93.5)	135 (86.0)	131 (91.6)
Missing, n (%)	52 (2.8)	26 (2.0)	11 (5.1)	8 (5.1)	7 (4.9)

TABLE 1B.

Participant and Household Characteristics in Youth and Young Adults with Diabetes in the research visit group of the SEARCH 4 Cohort Study by Food Security Status

		Food Secure (n=884)		Food Insecure (n=176)	
Participant Characteristics	**Overall (n=1060)**	**High food security (n=744)**	**Marginal food security (n=140)**	**Low food security (n=103)**	**Very low food security (n=73)**
Age (yrs), mean (sd)	20.7 (4.9)	20.5 (4.9)	21.2 (5.1)	20.8 (5.0)	21.3 (4.8)
10–17, n (%)	332 (31.3)	242 (32.5)	39 (27.9)	30 (29.1)	21 (28.8)
18–25, n (%)	566 (53.4)	397 (53.4)	76 (54.3)	54 (52.4)	39 (53.4)
26–35, n (%)	162 (15.3)	105 (14.1)	25 (14.1)	19 (18.5)	13 (17.8)
Sex					
Female, n (%)	562 (53.0)	385 (51.8)	85 (60.7)	50 (48.5)	42 (57.5)
Male, n (%)	498 (47.0)	359 (48.2)	55 (39.3)	53 (51.5)	31 (42.5)
Race/Ethnicity					
Asian American/Pacific Islander, n (%)	34 (3.2)	25 (3.4)	5 (3.6)	2 (1.9)	2 (2.7)
Hispanic, n (%)	244 (23.0)	174 (23.4)	39 (27.9)	19 (18.5)	12 (16.4)
Native American, n (%)	9 (0.9)	4 (0.5)	2 (1.4)	3 (2.9)	0 (0.0)
Non-Hispanic Black, n (%)	202 (19.1)	112 (15.1)	30 (21.4)	31 (30.1)	29 (39.7)
Non-Hispanic White, n (%)	567 (53.5)	426 (57.3)	64 (45.7)	48 (46.6)	29 (39.7)
Other, n (%)	3 (0.3)	2 (0.3)	0 (0.0)	0 (0.0)	1 (1.4)
Unknown, n (%)	1 (0.1)	1 (0.1)	0 (0.0)	0 (0.0)	0 (0.0)
Household income					
Less than $25,000, n (%)	202 (19.1)	98 (13.2)	43 (30.7)	32 (31.1)	29 (39.7)
$25,000 – 49,999, n (%)	234 (22.1)	137 (18.4)	41 (29.3)	36 (35.0)	20 (27.4)
$50,000 – 74,999, n (%)	166 (15.7)	113 (15.2)	20 (14.3)	19 (18.5)	14 (19.2)
$75,000 or greater, n (%)	379 (35.8)	338 (45.4)	25 (17.9)	10 (9.7)	6 (8.2)
Missing, n (%)	79 (7.5)	58 (7.8)	11 (7.9)	6 (5.8)	4 (5.5)
Parental education					
Less than high school graduate, n (%)	68 (6.4)	40 (5.4)	13 (9.3)	11 (10.7)	4 (5.5)
High school graduate, n (%)	152 (14.3)	77 (10.4)	36 (25.7)	25 (24.3)	14 (19.2)
Some college or Associate's, n (%)	335 (31.6)	224 (30.1)	41 (29.3)	35 (34.0)	35 (48.0)
Bachelor's or higher, n (%)	504 (47.6)	402 (54.0)	50 (35.7)	32 (31.1)	20 (27.4)
Missing, n (%)	1 (0.1)	1 (0.1)	0 (0.0)	0 (0.0)	0 (0.0)
Health Insurance					
None, n (%)	41 (3.9)	22 (3.0)	5 (3.6)	8 (7.8)	6 (8.2)
Other, n (%)	66 (6.2)	38 (5.1)	15 (10.7)	6 (5.8)	7 (9.6)
Medicaid/Medicare, n (%)	186 (17.6)	100 (13.4)	37 (26.4)	27 (26.2)	22 (30.1)
Private, n (%)	767 (72.4)	584 (78.5)	83 (59.3)	62 (60.2)	38 (52.1)
Diabetes duration, yrs. Mean (sd)	10.9 (3.3)	10.8 (3.3)	11.3 (3.2)	11.0 (3.2)	11.0 (3.4)

		Food Secure (n=884)		Food Insecure (n=176)	
Participant Characteristics	**Overall (n=1060)**	**High food security (n=744)**	**Marginal food security (n=140)**	**Low food security (n=103)**	**Very low food security (n=73)**
Insulin pump use					
Yes, n (%)	556 (52.5)	436 (58.6)	50 (35.7)	41 (39.8)	29 (39.7)
No, n (%)	488 (46.0)	299 (40.2)	86 (61.4)	59 (57.3)	44 (60.3)
Missing, n (%)	16 (1.5)	9 (1.2)	4 (2.9)	3 (2.9)	0 (0.0)
CGM use					
Yes, n (%)	352 (33.2)	280 (37.6)	37 (26.4)	23 (22.3)	12 (16.4)
No, n (%)	688 (64.9)	452 (60.8)	100 (71.4)	76 (73.8)	60 (82.2)
Missing, n (%)	20 (1.9)	12 (1.6)	3 (2.1)	4 (3.9)	1 (1.4)
HbA_{1c}*, %, mean (sd)	9.2 (2.0)	9.0 (1.9)	9.7 (2.1)	9.6 (2.2)	10.5 (2.2)
HbA_{1c}*, mmol/mol (sd)	77 (22)	74 (21)	82 (23)	82 (24)	91 (24)
Diabetic ketoacidosis episode					
Yes, n (%)	201 (19.0)	119 (16.0)	23 (16.4)	27 (26.2)	32 (43.8)
No, n (%)	830 (78.3)	610 (82.0)	110 (78.6)	72 (69.9)	38 (52.1)
Missing, n (%)	29 (2.7)	15 (2.0)	7 (5.0)	4 (3.9)	3 (4.1)
Severe hypoglycemia episode					
Yes, n (%)	112 (10.6)	77 (10.4)	9 (6.4)	15 (14.6)	11 (15.1)
No, n (%)	940 (88.7)	662 (89.0)	130 (92.9)	87 (84.5)	61 (83.6)
Missing, n (%)	8 (0.8)	5 (0.7)	1 (0.7)	1 (1.0)	1 (1.4)
Both DKA and severe hypoglycemia					
Yes, n (%)	29 (2.7)	15 (2.0)	0 (0.0)	9 (8.7)	5 (6.9)
No, n (%)	994 (93.8)	709 (95.3)	132 (94.3)	89 (86.4)	64 (87.7)
Missing, n (%)	37 (3.5)	20 (2.7)	8 (5.7)	5 (4.9)	4 (5.5)

TABLE 2.

Association of Household Food Insecurity with HbA_{1c}, Diabetic Ketoacidosis Episodes, and Severe Hypoglycemia Episodes

Clinical Outcome (continuous)	**Estimate**	**95% CI**
HbA1c *	0.334	0.003–0.657
Clinical Outcome (categorical)	**Odds Ratio**	**95% CI**
Diabetic Ketoacidosis *	1.58	1.13–2.21
Severe Hypoglycemia *	1.53	0.99–2.37

* Model adjusted for age, gender, race, participant education, parental education, income, health insurance, clinical site, insulin regimen, CGM use, diabetes duration