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Food Insecurity is Associated with High Risk Glycemic Control and Higher Health Care Utilization among Youth and Young Adults with Type 1 Diabetes

Jason A. Mendoza, MD, MPH[a,b,c], **Wren Haaland, MPH**[b], **Ralph B. D'Agostino Jr, PhD**[d], **Lauren Martini, MPH**[e], **Catherine Pihoker, MD**[a,b], **Edward A. Frongillo, PhD**[f], **Elizabeth J. Mayer-Davis, PhD**[h], **Lenna L. Liu, MD, MPH**[a,b], **Dana Dabelea, MD, PhD**[i], **Jean M. Lawrence, ScD, MPH, MSSA**[j], and **Angela D. Liese, PhD**[e,g]

[a]Department of Pediatrics, University of Washington, Seattle, WA, USA

[b]Seattle Children's Research Institute, Seattle, WA, USA

[c]Health Disparities Research Center, Fred Hutchinson Cancer Research Center/UW Cancer Consortium, Seattle, WA, USA

[d]Department of Biostatistical Sciences, Wake Forest University School of Medicine, Winston-Salem, NC, USA

[e]Department of Epidemiology and Biostatistics, University of South Carolina, Columbia, SC, USA

[f]Health Promotion, Education and Behavior, University of South Carolina, Columbia, SC, USA

[g]Center for Research in Nutrition and Health Disparities, Arnold School of Public Health, University of South Carolina, Columbia, SC, USA

[h]Departments of Nutrition and Medicine, University of North Carolina at Chapel Hill, Chapel Hill, NC, USA

[i]Department of Epidemiology, Colorado School of Public Health, University of Colorado-Denver Anschutz Medical Center, Denver, CO, USA

[j]Department of Research & Evaluation, Kaiser Permanente Southern California, Pasadena, CA, USA

[*]Correspondence: Jason A Mendoza, PO Box 5371, M/S: CW8-6, Suite 400, Seattle, WA 98145-5005; jason.mendoza@seattlechildrens.org; 206.884.1261 (telephone).

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Abstract

Aims—Household food insecurity (FI), i.e., limited availability of nutritionally adequate foods, is associated with poor glycemic control among adults with type 2 diabetes. We evaluated the association of FI among youth and young adults (YYA) with type 1 diabetes to inform recent clinical recommendations from the American Diabetes Association for providers to screen all patients with diabetes for FI.

Methods—Using data from the Washington and South Carolina SEARCH for Diabetes in Youth Study sites, we conducted an observational, cross-sectional evaluation of associations between FI and glycemic control, hospitalizations, and emergency department (ED) visits among YYA with type 1 diabetes. FI was assessed using the Household Food Security Survey Module, which queries conditions and behaviors typical of households unable to meet basic food needs. Participants' HbA_{1c} were measured from blood drawn at the research visit; socio-demographics and medical history were collected by survey.

Results—The prevalence of FI was 19.5%. In adjusted logistic regression analysis, YYAs from food-insecure households had 2.37 higher odds (95% CI: 1.10, 5.09) of high risk glycemic control, i.e., HbA_{1c} >9.0%, vs. peers from food-secure households. In adjusted binomial regression analysis for ED visits, YYAs from food-insecure households had an adjusted prevalence rate that was 2.95 times (95% CI [1.17, 7.45]) as great as those from food secure households.

Conclusions—FI was associated with high risk glycemic control and more ED visits. Targeted efforts should be developed and tested to alleviate FI among YYA with type 1 diabetes.

Keywords

pediatric; social determinants of health; hospitalizations; emergency department

1. Introduction

People with type 1 diabetes seek to achieve and maintain optimal glycemic control through three main components of diabetes care: glucose monitoring and medication self-management, physical activity, and nutrition therapy [1]. Optimal control reduces the risk of complications and premature mortality [1]. Over 50% of US youth with type 1 diabetes, however, do not achieve optimal glycemic control [2], and similar studies in other countries report even higher proportions [3–9]. Being of lower socioeconomic status (SES) has been associated with poorer glycemic control in multiple studies among youth with type 1 diabetes from multiple countries [10–15], and necessitates examination of modifiable factors for intervention.

Household food insecurity (FI), defined as limited or uncertain availability of nutritionally adequate and safe foods [16], can be a consequence of low SES but also reflects a household's access to food, food selection and preparation, and family, cultural, and social support [17]. FI may occur multiple times throughout a year, sometimes in a cyclical pattern, reflecting fluctuating periods of wages and/or safety net benefits [17]. FI may result in adverse changes to dietary intake, i.e., overconsumption when food is available and reduced intake when food is scarce [18]. FI may result in worry or anxiety about food scarcity, which is thought to increase risk of poor mental health [19], and which in turn may adversely impact dietary intake [18]. The importance of food security to diabetes care is recognized by the American Diabetes Association (ADA). Recently, the ADA recommended that all persons with diabetes should be screened for FI [20]. In 2015, 16.6% of US households with children experienced FI, which was higher than the rate (12.7%) for all US households [21].

Based on studies among adults with diabetes, FI may directly impair adherence to nutrition therapy due to inadequate healthy food and thus lead to suboptimal glycemic control and higher health care utilization [18]. FI may also adversely impact the two other main determinants of glycemic control: physical activity and glucose monitoring/medication self-management [18]. People with type 1 diabetes and FI may limit their physical activity due to inadequate dietary intake or hunger, or lack of resources for physical activity opportunities [22]; likewise, people with type 1 diabetes and FI may also struggle to obtain necessary supplies or medications to manage their diabetes due to limited household resources and the multitude of competing economic demands [23].

In the only pediatric study to investigate FI and diabetes, FI was associated with 3.5-fold higher odds of hospitalization among Canadian youth with type 1 diabetes or insulin-dependent type 2 diabetes [23]. Similar studies among middle-aged and older adults with type 2 diabetes lend support that FI adversely affects self-management of diabetes, glycemic control, and health care utilization [24–27]. Thus, among a diverse US subsample of youth and young adults (YYA) with type 1 diabetes from two of the five sites of the SEARCH for Diabetes in Youth Study (SEARCH), we conducted a study to estimate 1) the prevalence of FI and 2) the association of FI with glycemic control and health care utilization [28].

2. Materials, and Methods

SEARCH is a multi-center observational study that initiated ascertainment of youth <20 years of age with physician-diagnosed diabetes in 2001, and is described in detail elsewhere [28]. Briefly, SEARCH identified prevalent (existing) cases of diabetes in 2001 and 2009, and incident (newly-diagnosed) cases from 2002 through the present. In SEARCH 3 (funding cycle 2010–2015), persons <20 years of age with incident type 1 or 2 diabetes or other type (maturity onset diabetes in youth, hybrid type, etc.) diagnosed in 2008 or 2012 were invited for a baseline study visit consisting of questionnaires, physical examinations, and laboratory measures, henceforth called the "Registry Visit". Participants ≥18 years of age completed questionnaires themselves and participants <18 years of age or their parent/guardian completed questionnaires. SEARCH 3 also included a follow-up visit for a subsample of YYA that had one or more research visits in earlier years of the SEARCH study, which were called "Cohort Visits". The FI study was conducted from November 2013 through June of 2015. The survey on FI was completed during the SEARCH visits at which time blood samples were drawn for the main SEARCH study. The SEARCH Study and the FI study were approved by the local institutional review boards. The South Carolina (SC) and Washington State (WA) SEARCH sites (2 of the 5 sites) collected data on FI for this study. Participants provided informed consent (if ≥18 years old) or assent (if <18 years old) along with parental consent before FI data collection. For these analyses, we restricted our sample to YYA with type 1 diabetes, due to the small sample size of YYA with type 2 diabetes (n=83).

2.1 Main Exposure

We ascertained FI using the 18-item US Department of Agriculture's (USDA) Household Food Security Survey Module (HFSSM). The HFSSM measures FI over the previous 12 months [16] and begins by querying respondent's agreement with statements on food insecurity such as "we worried whether our food would run out before we got money to buy more." These statements increase in severity for describing food insecurity and culminate in the final statement, which asks if household members or children ever did not eat for a whole day because there was not enough money for food. Households with children respond to 18 items whereas households without children respond to 10 items. For participants <18 years of age, their parents/guardians completed the HFSSM, while participants 18 years and older completed the HFSSM themselves.

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 FI. The USDA provides equivalent standardized scale values from 0 to 10 for both types of households, termed the "standard 0–10 metric," to allow for direct comparisons [16] between households with and without children. Additionally, the HFSSM scores can be grouped into categories: food insecure (encompassing low food security and very low food security) and food secure (encompassing high and marginal food security) [29]. HFSSM's reliability has been reported, e.g., Cronbach's alpha = 0.86–0.93 [30] and validity has been established [31].

2.2 Dependent Variables

Whole blood samples were analyzed for HbA_{1c} by the Northwest Lipid Metabolism and Diabetes Research Laboratories in Seattle, WA, using an automated nonporous ion-exchange high-performance liquid chromatography system (model G-7; Tosoh Bioscience, Montgomeryville, Pennsylvania) [2]. HbA_{1c} is the standard measure of glycemic control over the past 3 months and is the primary dependent variable. We also used the ADA and International Society for Pediatric and Adolescent Diabetes (ISPAD) 2014 Guidelines for HbA_{1c} to categorize participants' glycemic control: for ages <18 years, 1) <7.5% is optimal, 2) 7.5–9.0% is suboptimal, and (3) >9.0% is high risk [32, 33]; for ages ≥18 years, 1) <7.0% is optimal, 2) 7.0–9.0% is suboptimal, and 3) >9.0% is high risk [2, 32, 33].

For a subsample analysis, we examined two measures of healthcare utilization; the number of hospitalizations and number of emergency department (ED) visits in the last 6 months, which was collected from Cohort Visit participants only.

2.3 Covariates

SEARCH collected data via questionnaire on parental education, household income, and diabetes duration, health insurance status, age (at diagnosis and at each visit), sex, and race and ethnicity (Hispanic, African American, Asian or Pacific Islander, American Indian, non-Hispanic White, and other race), with the last two variables collected using US Census

Bureau questions [34]. We queried receipt of household food assistance by asking whether any member of the household received benefits in the last 12 months from (a) the US federal Supplemental Nutrition Assistance Program (SNAP; formerly known as "Food Stamps"), (b) the US federal Special Supplemental Nutrition Program for Women, Infants, and Children (WIC), and (c) local food banks or soup kitchens [35]. Receiving household food assistance was defined as answering "yes" to any of those three questions. Similarly, we also asked if any child in the household receives lunch in the last 12 months from the US federal free or reduced-price lunch program at school [35]. The US free or reduced-price lunch program, also called the National School Lunch Program, is a federally assisted meal program that provides nutritious meals daily at low- or no-cost to children who qualify based on low income status and who attend public or nonprofit private schools [36].

SEARCH also queried all participants regarding their current treatment of diabetes using insulin or tablets/pill (e.g., metformin). Among Cohort Visit participants only, SEARCH queried insulin regimen and categorized as follows: 1) pump, 2) multiple daily injections (MDI, ≥3/day): glargine or detemir plus rapid-acting insulin (insulin lispro, insulin aspart, or insulin glulisine), 3) MDI: glargine or determir insulin plus NPH insulin plus regular or rapid-acting insulin, 4) MDI: any insulin type excluding basal insulin (glargine or detemir), 5) one to two injections per day, excluding insulin glargine or detemir, or none reported (i.e., not currently taking insulin or refuse to specify regimen) [37].

Household income and parent education have moderate to high correlations [38, 39], but were missing for n=26 and n=6 participants, respectively. Therefore, we created a composite, dichotomous SES variable using household income and parent education data. We defined lower SES as household income <$50,000/year (as an approximation of median household income) [40] regardless of parent education category, or parent education less than a bachelor's degree if income data was missing. We defined higher SES as household income ≥$50,000/year and any parent education category, or ≥bachelor's degree if income data was missing. Using this composite SES variable resulted in only 5 participants with missing SES data.

2.4 Statistical Analyses

The prevalence of FI was estimated as a simple proportion with 95% confidence intervals. For the adjusted models described, we initially included current use of insulin and diabetes-related medications as two covariates; however, these two covariates did not substantially change the adjusted models' estimates, likely due to a lack of variability (i.e., 98.4% currently used insulin and 2.7% currently used diabetes-related tablets/pills). Thus, we excluded both covariates from further analyses.

To evaluate the association of FI and glycemic control, we first used logistic regression with glycemic control category as a dichotomous dependent variable, i.e., high risk versus combined optimal and suboptimal categories (HbA_{1c} >9.0%). Categorical FI status (food insecure versus food secure) served as the main exposure variable. The model also included participant age at visit, sex, race/ethnicity, SES, SEARCH site, time since diabetes diagnosis, and health insurance type.

We also examined the association of FI and glycemic control using linear regression with continuous HbA_{1c} as the dependent variable and FI (as the continuous "standard 0–10 metric" score) as the main exposure variable. Visual inspection of FI and HbA_{1c} indicated many FI scores of zero, i.e., persons with high food security, thus we included a FI dichotomous term (FI score=0 versus score ≥0) to better describe participants with FI scores ≥0, i.e., marginal, low, and very low food security. Due to the nonlinear relationship of HbA_{1c} and FI continuous scores, we also included a FI-squared term in the linear regression model. These models were adjusted for participant age, sex, race/ethnicity, SES, SEARCH site, duration of diabetes diagnosis, and health insurance type. The adjusted model with the three FI terms had a lower Akaike Information Criteria than the adjusted model with only a continuous FI term, indicating improved model fit for the former, which we present as the primary adjusted model for HbA_{1c}. From this adjusted model, we additionally calculated estimates of HbA_{1c} by the four food insecurity categories (high, marginal, low, and very low food security).

Analyses for health care utilization examined counts of days hospitalized or ED visits among the subsample of cohort visit participants. We used negative binomial regression with the count of hospitalizations as the dependent variable. FI measured as a dichotomous term (food secure vs. insecure) was the main exposure variable. We included the following covariates: participant age, sex, race/ethnicity, SES, SEARCH site, duration of diabetes diagnosis, health insurance type, and insulin regimen. Because this data is cross-sectional, the negative binomial regression model provides an adjusted prevalence ratio (PR) comparing the prevalence of FI among participants in food insecure versus food secure households. A separate, similarly adjusted negative binomial regression examined the count of ED visits as the dependent variable. Data analyses were conducted using STATA 12.0 in 2016–2017 (StataCorp LLC, College Station, USA).

A sample of n=289 who were enrolled in this study served as the starting point for analyses (Supplemental Figure S1). These constituted 71.4% of the 405 SEARCH 3 participants with type 1 diabetes who participated in a Registry or Cohort visit at the WA and SC sites during the same period. For analysis of the prevalence of FI, participants with any missing information on FI were excluded (n=20) resulting in a sample of 269. For the primary analysis on the association of FI and glycemic control, participants were excluded due to missing data for FI (n=16), HbA_{1c} (n=36), or both (n=4). Finally, additional participants (n=7) were excluded due to missing data for covariates, yielding a final analytic sample of n=226. Comparing demographic characteristics of included versus excluded ancillary study participants yielded significant differences at $p<0.05$: included participants were younger (15.6 vs. 17.7 years old), had a shorter duration of diabetes (79.5 vs. 92.0 months), and were more likely from the South Carolina site (90.3% of South Carolina participants vs. 71.5% of the Washington state participants); there were no significant differences for sex or race/ethnicity, both $p>0.05$. The planned subsample adjusted analyses on healthcare utilization involving the cohort participants had a sample size of n=203.

3. Results

The average age of YYAs included in the final analytic study sample (n=226) was 15.6 ± 5.4 years, 52.2% were female, 75.2% were non-Hispanic White (4.9% Asian or Pacific Islander, 15.0% non-Hispanic Black, 4.4% Hispanic, and 0.4% Other Race), and the average duration of diabetes was 79.5 months or 7.5 years (Table 1). More than half (57.8%) of the participants had parents with less than a bachelor's degree, 46.2% had an annual household income <$50,000, and 48.7% had Medicaid or other governmental health insurance. Only 13.7% of the sample had HbA_{1c} levels in the optimal range while 39.4% in the suboptimal range and 46.9% were in the high risk range. As expected, several characteristics significantly differed between food secure and food insecure participants including SES, health insurance, free/reduced price lunch and household food assistance, with greater proportions of food insecure participants showing greater economic deprivation and receipt/ enrollment in public insurance and food assistance programs (Table 1 with unadjusted comparisons). Mean HbA_{1c} levels were 9.8% (84 mmol/mol) among participants living in food insecure households compared to 9.0% (75 mmol/mol) among those from food secure households (p=0.02). Participants from food insecure households also had a larger number of hospitalizations (0.9 versus 0.2, p=0.001) and ED visits (1.6 versus 0.3, p<0.001) in the last 6 months compared to those who were from food secure households, respectively.

The prevalence of FI, which was calculated using participants who had FI data, regardless of missing covariates (n=269), was 19.0% for the total sample (Figure 1), with 7.1% who lived in households with very low food security (not shown). The prevalence of FI did not differ by sex, age group, or study site (Figure 1, all p>0.05).

We first evaluated the association between food insecurity and HbA_{1c} by focusing on high risk glycemic control. Participants living in food insecure households had 2.64 higher odds (95% CI [1.32, 5.25]) of high risk glycemic control compared to those living in food secure households as estimated in the unadjusted logistic regression model. This association with FI was attenuated slightly but remained statistically significant (OR=2.37; 95% CI [1.10, 5.09]) after adjustment for covariates (Table 2).

Participants living in food insecure households had an adjusted prevalence rate of hospitalizations that was 2.96 times as great as those from food secure households (PR=2.96; 95% CI [0.92, 9.51]), although this result was not significant at the 0.05 level with p=0.07. For ED visits, participants living in food insecure households had an adjusted prevalence rate that was 2.95 times as great as those from food secure households (PR=2.95; 95% CI [1.17, 7.45], p=0.02) (Table 2).

Supplemental Figure S2 additionally explores the role of severity of food insecurity on its relationship with HbA_{1c} and provides the adjusted model prediction for HbA_{1c} by the traditional four food security categories. Participants from households with low and very low food security had higher HbA_{1c} (9.9%, 95% CI [9.4, 10.5] and 9.9%, 95% CI [9.2, 10.6], respectively) than participants from households with marginal (8.7%, 95% CI [7.9, 9.6]) and high food security (9.0%, 95% CI [8.8, 9.3]), although these differences were not significant (all p>0.05).

Lastly, we explored the shape of the relationship of continuously scaled FI and HbA_{1c}. FI was significantly associated with HbA_{1c} (beta=0.15; 95% CI [0.01, 0.29]) in an unadjusted linear regression analysis (n=233, R^2=0.02). In the adjusted linear regression model (n=226, R^2=0.20), which included continuous, dichotomous, and squared FI terms, the resulting association between FI and HbA_{1c} levels is shown in Figure 2, which depicts a non-linear relationship and focuses on participants with marginal, low, and very low food security, i.e., any affirmation of food insecurity. The interpretation of FI from the fully adjusted model as shown in Figure 2 is as follows: the continuous FI term suggests that the higher the FI, the higher the HbA_{1c} (beta=1.63; 95% CI [0.60, 2.65]). This positive linear relationship occurred in the marginal and low food security range, and continues until the standardized FI score reaches 4.5 (near the threshold differentiating low from very low food security) where HbA_{1c} is also highest. Thereafter, the squared FI term indicates that with higher FI, HbA_{1c} declines, as the squared FI term was inversely associated with HbA_{1c} (beta=−0.19; 95% CI [−0.31, −0.06]). This finding indicates that persons with the highest levels of FI actually have the lowest levels of HbA_{1c}.

4. Discussion

We report that almost 20% of YYA with type 1 diabetes in this sample experienced FI. This prevalence of FI was substantially higher than the US national prevalence of FI (12.7%), the prevalence for South Carolina (13.2%), and for Washington State (12.9%) [21]. Our prevalence estimates are similar to estimates obtained by the Canadian study of youth with diabetes, which reported a FI prevalence of 21.9% among a cross-sectional sample of 183 youth (mean age of 12 years) with type 1 diabetes or type 2 diabetes requiring insulin [23]. Just as in our study, Marjerrison et al. found a substantially higher prevalence of FI in their sample with diabetes than among regional or national samples [23].

We did not find any differences in FI prevalence in YYA with type 1 diabetes by age group or by sex. In contrast, previous studies in adults with type 2 diabetes reported that women have a higher prevalence of FI than men [41]. Previous research has speculated that mothers protect their children, especially young children, from FI [42]; accordingly, we would expect youth to have a lower prevalence of FI than young adults, which we did not find. The lack of association may be due to the older age distribution in the present study, which did not include substantial numbers of young children.

Altogether, greater FI was associated with high risk glycemic control (i.e., very poor levels of glycemic control). The Canadian study did not find associations between FI and HbA_{1c} >9.0% [23]. Differences in findings for HbA_{1c} may be due to the larger sample size of the present study (n=226 vs 183 in the Canadian study), analysis of HbA_{1c} as a continuous variable, or differences in population characteristics or health care systems. For example, the present study included YYA with type 1 diabetes (mean age 15.6 years) while the Canadian study included participants ≥18 years of age with type 1 diabetes or insulin dependent type 2 diabetes (mean age 11.8 years).

Our findings on the adjusted association of FI and high risk glycemic control (OR=2.37, 95% CI [1.10, 5.09]) are also consistent with multiple previous studies among primarily older adults with type 2 diabetes [24, 25, 43]. Several of these have found associations of similar magnitude to our study, including odds ratios ranging from 1.48 [24] to 2.15 [43], though not all have found significant associations [44].

Importantly, we further evaluated the impact of different levels of FI on glycemic control via a traditional four-group categorized analysis of FI and an explicit statistical analysis of the shape of the association. Although there were no significant differences in mean HbA_{1c} among the four-group categories of FI, this is not surprising given the relatively small sample size for this categorical analysis. In contrast, we found a significant and complex, inverted U-shaped non-linear relationship of FI with HbA_{1c}: (a) in the marginal and low food security range of the continuous FI score, higher food insecurity was associated with higher HbA_{1c} and (b) in the very low food security range of the squared FI score, higher food insecurity was associated with lower $HbA_{1c.}$ These findings may relate to the changing nature of FI across the continuum of the FI spectrum, ranging from experiences of worry about having enough food, lack of balanced meals, cutting the amount of foods consumed to skipping meals or going without food for a whole day. The novel finding that persons with marginal food security, who technically are classified by the USDA as food secure [29], had elevated risk of higher HbA_{1c} (Figure 2) requires confirmation, although it is supported by other studies that reported associations with marginal food security and other adverse health outcomes also [45]. In its most extreme form (i.e. very low food security), FI is likely experienced physiologically as a fasting state, albeit unintentional. Multiple studies from a recent review have shown that intentional fasting, such as for religious reasons, is associated with lower HbA_{1c} levels [46]. Similarly, among SEARCH participants, unintentional fasting due to extreme levels of FI may also lower their HbA_{1c} levels. Thus, current ADA recommendations for screening for FI [20] may be inadequate because they would not identify persons with marginal food security nor would they differentiate very low from low food security. However, promising qualitative research indicates that simply screening for food insecurity in the clinical setting may respectfully open up a larger discussion about food insecurity between patients and clinicians,[47] which may be sufficient to provide appropriate support for patients.

The results of our analyses examining health care utilization provide additional insight on the inverse relationship at the higher levels of FI and HbA_{1c}. In adjusted models, participants from FI households had an almost 3-fold higher prevalence rate of ED visits in the past 6 months compared to their food secure peers. A similar higher prevalence rate was also found for hospitalizations among food-insecure participants, although this finding was not significant (p=0.07) due to either there being no relationship or inadequate power to detect one. We speculate that although the highest levels of FI were associated with the lowest average levels of HbA_{1c}, the concomitant increase in the rate of ED visits suggests that this apparent improvement in glycemic control may occur through an unhealthy mechanism, i.e., unintentional inadequate or irregular dietary intake due to food scarcity rather than through intentional improvements to glucose monitoring and medication self-management, physical activity, and nutrition therapy. Our sample reported too few episodes of hypoglycemia for us to evaluate whether this was a key reason for health care utilization or not. This finding of an association between FI and higher health care utilization is also consistent with the other study examining food insecurity among youth with diabetes. Among Canadian youth with type 1 diabetes or insulin dependent type 2 diabetes, Marjerrison and colleagues reported almost 3.7 higher odds of hospitalizations among youth living in food insecure households compared to those from food secure households [23].

Altogether, these findings suggest that policies and programs to identify and alleviate FI among YYA with type 1 diabetes may improve their glycemic control and could potentially reduce hospitalizations and ED visits. These findings provide support for the ADA's newly recommended FI screening guidelines for all persons with diabetes [20] and also are consistent with the recent American Academy of Pediatrics policy statement on screening, promoting, and advocating for food security for all children and adolescents [48]. Examination of mechanisms by which FI adversely impacts glycemic control and health care utilization are needed. Moreover, FI has already been associated with increased risk of depression, dysthymia, behavioral problems, and poor social skills in general populations of older children, as well as iron-deficiency anemia, poor reported health status, poor physical function, and poor psychosocial function in young children [45, 49–59]. Thus, identifying and alleviating FI among YYA with type 1 diabetes would also help to ensure optimal general health and development [48]. As an important social determinant of health, FI is a complex issue that merits consideration at multiple levels of influence, i.e., individual, family, school, community, state, and federal levels. While screening for FI by diabetes providers is a necessary first step, alleviating food insecurity will likely require coordinated efforts of policy-makers, nongovernmental organizations, diabetes and food assistance advocacy groups, as well as health systems.

Strengths of our study include using the USDA's HFSSM, the US reference measure of FI, a sufficiently large sample size of YYA with type 1 diabetes, and HbA_{1c}, the criterion standard for long term glycemic control. Limitations include: 1) the cross-sectional design precludes interpreting the directionality of associations, 2) generalizability, due to enrolling participants from only South Carolina and Washington which are representative of the Southeastern US and Pacific Northwest but not necessarily of other regions, 3) lack of daily self-monitoring of blood glucose data precludes examining associations with glycemic control in finer detail, 4) low frequency of hypoglycemia (n=6 episodes) precludes examining associations with this outcome, 5) lack of psychological or family support variables, which should be examined in future studies, and 6) lack of specific diagnoses for hospitalizations or ED visits. Despite not knowing specific hospitalization or ED visit diagnoses, the increased risk associated with FI likely reflects the vulnerability of these families and the numerous social determinants adversely impacting their health.

In conclusion, almost 20% of our sample of YYA with type 1 diabetes experienced FI, which is higher than national US rates. FI was associated with high risk glycemic control. Greater FI was associated with higher HbA_{1c} but only at low and moderate levels of FI. Unexpectedly, at the highest levels of FI, greater FI was associated with lower HbA_{1c}, which may reflect similarities to a fasting state. Finally, higher FI was associated with higher rates of ED visits. Interventions to alleviate FI among YYA with type 1 diabetes may improve glycemic control and reduce health care utilization.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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The findings and conclusions in this report are those of the authors and do not necessarily represent the official position of the Centers for Disease Control and Prevention and the National Institute of Diabetes and Digestive and Kidney Diseases.

Abbreviations

ADA	American Diabetes Association
ED	Emergency department
HFSSM	Household Food Security Survey Module
FI	Household food insecurity
ISPAD	International Society for Pediatric and Adolescent Diabetes
MDI	Multiple daily injections
PR	Prevalence ratio

SES	Socioeconomic status
SEARCH	SEARCH for Diabetes in Youth Study
SC	South Carolina
USDA	United States Department of Agriculture
WA	Washington State
YYA	Youth and young adults

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Highlights

- Youth and adults with T1D had higher food insecurity than the national population
- Food insecurity was associated with high risk glycemic control
- Food insecurity was associated with more emergency department visits
- Programs are needed to alleviate food insecurity among youth and adults with T1D

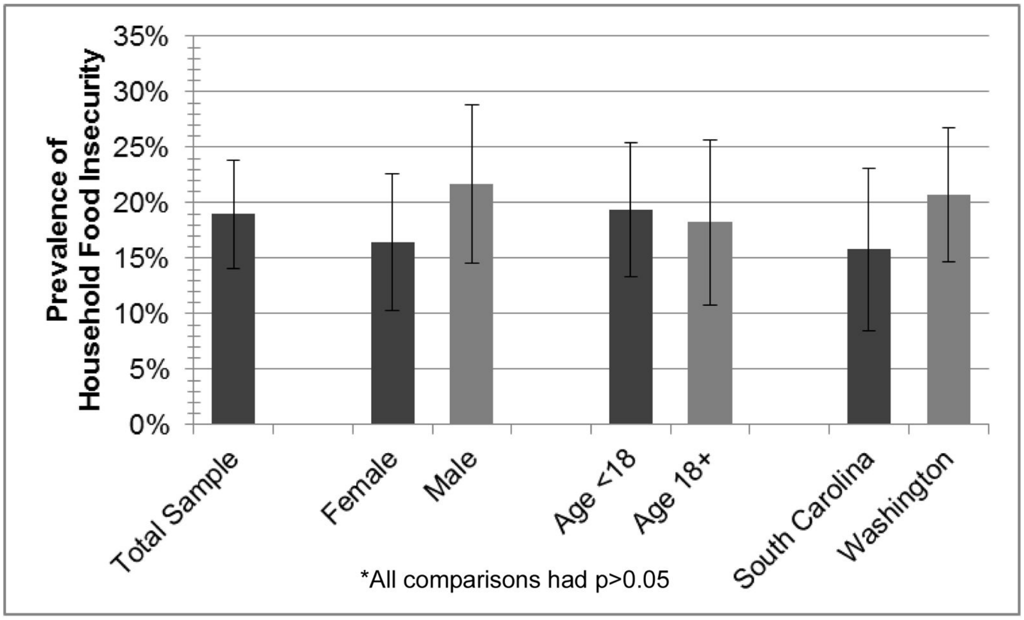

Figure 1.

Prevalence of food insecurity among SEARCH participants with type 1 diabetes from the SEARCH Food Insecurity study, and stratified by sex, age group and study site, n=269.

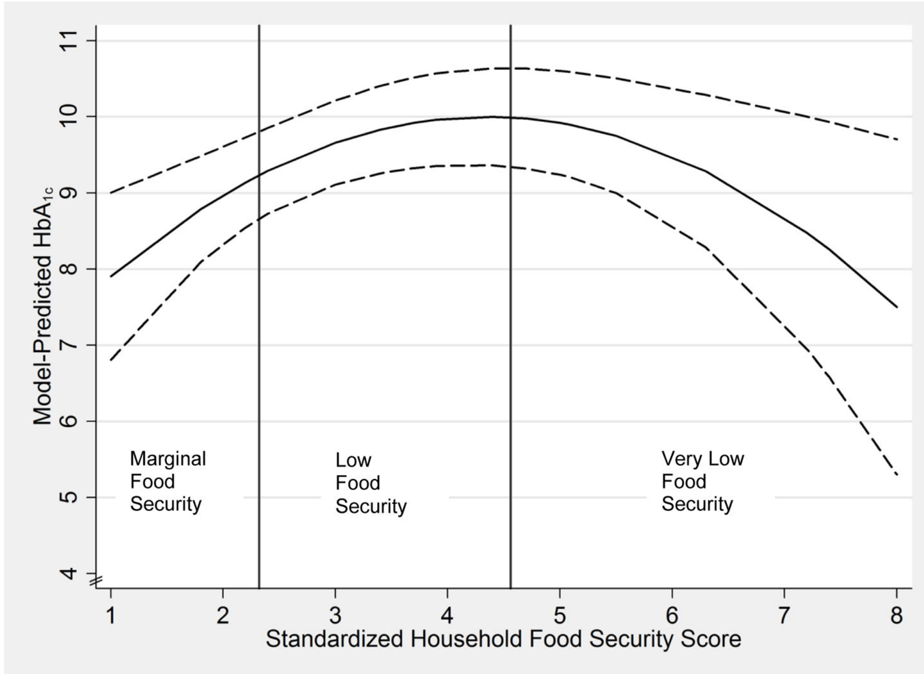

Figure 2.

Adjusted* multiple linear regression model for HbA_{1c} with 95% confidence intervals predicted by three food insecurity terms (dichotomous, continuous, and squared) among participants with any food insecurity in the SEARCH Food Insecurity study.

*Adjusted for participant age, sex, race/ethnicity, SES, study site, duration of diabetes diagnosis, and health insurance type. Dotted lines represent 95% confidence intervals. Not shown: participants with high food security (standardized score=0). Food Insecurity is inclusive of Low and Very Low Food Security categories.

Table 1

Characteristics of participants with type 1 diabetes in the SEARCH Food Insecurity study 2013–2015 in the South Carolina and Washington sites by household food insecurity status, n=226.

	Total (n=226)	Food Secure (n=182)	Food Insecure (n=44)	p^*
Age at Study visit (years), *mean (sd)*	15.6 (5.4)	15.5 (5.6)	16.0 (4.8)	0.599
Male, *n (%)*	108 (47.8)	83 (45.6)	25 (56.8)	0.181
Race/Ethnicity, *n (%)*				
Non-Hispanic White	170 (75.2)	136 (74.7)	34 (77.3)	0.725
Other race/ethnicity	56 (24.8)	46 (25.3)	10 (22.7)	
Diabetes Duration (months), *mean (sd)*	79.5 (40.7)	78.8 (40.6)	82.0 (41.2)	0.643
SEARCH Study Site, *n (%)*				0.161
South Carolina	93 (41.2)	79 (43.4)	14 (31.8)	
Washington	133 (58.8)	103 (56.6)	30 (68.2)	
Highest Parent Education, *n (%)*				0.004
Bachelor's or higher	95 (42.2)	85 (47)	10 (22.7)	
Less than Bachelor's	130 (57.8)	96 (53)	34 (77.3)	
Family Income, *n (%)*				<0.001
≥ $50,000	99 (53.8)	91 (63.6)	8 (19.5)	
<$50,000	85 (46.2)	52 (36.4)	33 (80.5)	
Socioeconomic Status[†], *n (%)*				<0.001
Higher	114 (50.4)	105 (57.7)	9 (20.5)	
Lower	112 (49.6)	77 (42.3)	35 (79.5)	
Health Insurance, *n (%)*				0.017
Private	99 (43.8)	89 (48.9)	10 (22.7)	
Public (Federal or State)	110 (48.7)	81 (44.5)	29 (65.9)	
Other	8 (3.5)	6 (3.3)	2 (4.5)	
None	9 (4.0)	6 (3.3)	3 (6.8)	
Free/Reduced Price Lunch, *n (%)*	45 (20.3)	22 (12.2)	23 (56.1)	<0.001
Household Food Assistance, *n (%)*	63 (28.0)	31 (17.0)	32 (74.4)	<0.001
HbA_{1c} %, *mean (sd)*	9.2 (1.9)	9.0 (1.9)	9.8 (1.8)	0.021
HbA_{1c} mmol/mol, *mean (sd)*	77 (21)	75 (21)	84 (20)	0.021
Glycemic Control Category, *n (%)*				0.006
Optimal	31 (13.7)	30 (16.5)	1 (2.3)	
Suboptimal	89 (39.4)	75 (41.2)	14 (31.8)	
High Risk	106 (46.9)	77 (42.3)	29 (65.9)	
Insulin use, *n (%)*	223 (98.7)	179 (98.4)	44 (100)	0.391
Oral diabetes medications use, *n (%)*	6 (2.7)	6 (3.3)	0 (0)	0.222
Hospitalizations[‡], *mean (sd)*	0.3 (1.3)	0.2 (0.7)	0.9 (2.4)	0.001
Any Hospitalizations[‡], *n (%)*	25 (12.3)	17 (10.3)	8 (20.5)	0.080
ED visits[‡], *mean (sd)*	0.6 (1.9)	0.3 (1.0)	1.6 (3.7)	<0.001
Any ED visits[‡], *n (%)*	45 (22.1)	29 (17.6)	16 (41.0)	0.001

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	Total (n=226)	Food Secure (n=182)	Food Insecure (n=44)	*p* *
Insulin Regimen, *n (%)*				0.014
Pump	107 (52.5)	94 (57.0)	13 (33.3)	
MDI: glargine/rapid	39 (19.1)	27 (16.4)	12 (30.8)	
MDI: glargine/rapid plus other	34 (16.7)	24 (14.5)	10 (25.6)	
MDI: no glargine	11 (5.4)	7 (4.2)	4 (10.3)	
One to two injections/no glargine	10 (4.9)	10 (6.1)	0 (0)	
None reported	3 (1.5)	3 (1.8)	0 (0)	

*P-value for comparisons between food secure and food insecure groups using Pearson's chi-squared and student's t-test.

†Lower socioeconomic (SES) was defined as household income <$50,000/year and any parent education category, or parent education <bachelor's degree if income data was missing; higher SES was defined as household income ≥$50,000/year and any parent education category, or ≥bachelor's degree if income data was missing.

‡Hospitalizations, ED (Emergency Department) visits, and insulin regimen were collected among Cohort Visit participants only. This subsample, n=204, represents cohort participants who had these data as well as food insecurity and covariates. MDI is multiple daily injections.

Table 2

Association of household food insecurity (food insecure versus secure) with high risk glycemic control, hospitalizations, and emergency department visits among individuals with Type 1 Diabetes in the SEARCH Food Insecurity study (2013–2015)

Outcomes	Model 1 (Unadjusted)		Model 2 (adjusted)	
	Coefficient (95%CI)	**Sample size, Model Pseudo R^2**	**Coefficient (95%CI)**	**Sample size, Model Pseudo R^2**
High risk glycemic control *	2.64 (1.32, 5.25)	n=226, R^2=N/A	2.37 (1.10, 5.09)	n=226, R^2=N/A
Hospitalizations †	4.91 (1.46, 16.51)	n=203 R^2=0.03	2.96 (0.92, 9.51)	n=203 R^2=0.19
ED visits †	4.75 (2.05, 11.02)	n=203 R^2=0.04	2.95 (1.17, 7.45)	n=203 R^2=0.16

*Logistic regression analyses. N/A=not applicable. Model 2 adjusted for age, sex, race/ethnicity, socioeconomic status, study site, diabetes duration, and health insurance.

†Negative binomial regression analyses involving Cohort participants only, the subsample of participants who completed questions on hospitalizations, Emergency Department (ED) visits, and insulin regimen. Model 2 adjusted for age, sex, race/ethnicity, socioeconomic status, study site, diabetes duration, health insurance, and insulin regimen.