

Food Insecurity in Relation to Changes in Hemoglobin A_{1c}, Self-Efficacy, and Fruit/Vegetable Intake During a Diabetes Educational Intervention

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OBJECTIVE— Food insecurity is hypothesized to make diabetes self-management more difficult. We conducted a longitudinal assessment of food insecurity with several diabetes self-care measures.

RESEARCH DESIGN AND METHODS—We conducted a secondary, observational analysis of 665 low-income patients with diabetes, all of whom received self-management support as part of a larger diabetes educational intervention. We analyzed baseline food insecurity (measured by the U.S. Department of Agriculture Food Security module) in relation to changes in hemoglobin A_{1c} (HbA_{1c}) as well as self-reported diabetes self-efficacy and daily fruit and vegetable intake. We examined longitudinal differences using generalized estimating equation linear regression models, controlling for time, age, sex, race, income, and intervention arm.

RESULTS—Overall, 57% of the sample had an income <\$15,000. Participants who were food insecure (33%) were younger, had less income, and were more likely to be unemployed compared with participants who were food secure. At baseline, those who were food insecure had higher mean HbA_{1c} values (8.4% vs. 8.0%) and lower self-efficacy and fruit and vegetable intake than those who were food secure (all $P < 0.05$). Compared with food-secure individuals, participants who were food insecure had significantly greater improvements in HbA_{1c} over time (0.38% decrease compared with 0.01% decrease; P value for interaction <0.05) as well as in self-efficacy (P value for interaction <0.01). There was no significant difference in HbA_{1c} by food security status at follow-up.

CONCLUSIONS—Participants experiencing food insecurity had poorer diabetes-related measures at baseline but made significant improvements in HbA_{1c} and self-efficacy. Low-income patients who were food insecure may be particularly receptive to diabetes self-management support, even if interventions are not explicitly structured to address finances or food security challenges.

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Food insecurity refers to going hungry, or being at risk of going hungry, because of the inability to afford food; food insecurity occurs when “the availability of nutritionally adequate and

safe foods or the ability to acquire acceptable foods in socially acceptable ways is limited or uncertain” (1). In 2010, the U.S. Department of Agriculture estimated that 14.5% of U.S. households (more than

17 million households) were food insecure (2). Households of racial/ethnic minorities (i.e., black or Hispanic/Latino), households with incomes near or below the federal poverty line (\$23,000 for a family of four), and households headed by a single parent are significantly more likely to experience food insecurity (2).

Food insecurity poses additional challenges for those with diabetes. There are a number of mechanisms through which food insecurity is hypothesized to predispose individuals with diabetes toward poorer self-management of the disease. First, they may shift their dietary intake away from relatively expensive fruits and vegetables and toward foods that are relatively less expensive but more calorically dense, such as refined carbohydrates, added sugars, and fats. These foods may negatively impact glycemic control. Second, day-to-day changes in the availability of food may result in parallel fluctuations in blood glucose levels, which may make glycemic control more challenging. Finally, food insecurity may reduce self-efficacy or the confidence in one’s ability to perform diabetes self-management behaviors successfully. Previous cross-sectional analyses have documented such relationships between food insecurity and higher hemoglobin A_{1c} (HbA_{1c}) (3–7), increased risk of hypoglycemia (8,9), lower diabetes self-efficacy (4), and poorer nutritional intake (10).

However, these associations are based on results from cross-sectional studies, and no previous studies have examined these relationships in the context of a diabetes intervention. In this study, we sought to examine the relationship between food insecurity and HbA_{1c} longitudinally, along with secondary outcomes of self-reported diabetes self-efficacy and dietary intake of fruits and vegetables. We hypothesized that participants who are food insecure in a diabetes self-management intervention would have greater challenges with diabetes self-management and poorer HbA_{1c} control

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over time compared with participants who are food secure.

RESEARCH DESIGN AND METHODS

Study setting

The Missouri Health Literacy and Diabetes Communication Initiative was an intervention conducted in low-income primary care clinics in 2008 and 2009. The intervention assessed the effectiveness of administering self-management support using diabetes educational guide (Living with Diabetes: An Everyday Guide for You and Your Family) sponsored by the American College of Physicians Foundation; this guide was designed to assist patients across health literacy levels in the development of self-management action plans. This patient-centered education was, therefore, focused on behavior change in addition to knowledge acquisition.

The intervention was a clinic-clustered, randomized trial that examined different strategies for implementing the intervention. Clinics were randomized to 1) a carve-in arm (clinic staff received brief training and implemented self-management support themselves), 2) a carve-out arm (a dedicated off-site coordinator implemented self-management support via phone calls), and 3) an off-protocol arm. In the off-protocol arm, clinics designed their own diabetes quality improvement projects without use of the educational guide in response to the Health Disparities Collaborative sponsored by the Health Resources and Services Administration, which supported federally funded health centers in the adoption of the Chronic Care and Improvement Models to improve diabetes care for underserved populations (11). The intervention was conducted in urban, suburban, and rural safety net sites in Missouri. Nine clinics within two federally qualified health centers and one university-based system, which provides care to low-income patients in four clinics, participated. Adult participants with diabetes were eligible to participate if they received primary care in a participating clinic, had an HbA_{1c} level >6.5%, spoke English, and had no significant auditory, visual, or cognitive impairments.

We enrolled 665 patients in the trial, with a participation rate of 80% across sites using American Association for Public Opinion Research guidelines. The study was approved by the institutional

review boards at Northwestern University, University of Missouri, and the Copernicus Group.

Key measures

As part of the larger diabetes intervention, we administered a computer-based survey to trial participants at baseline, 3 months, and 1 year (in person, over the phone, or both) and abstracted laboratory data from the electronic medical record. This study examined these survey and medical record variables as a secondary, observational analysis nested within the randomized trial.

The primary predictor variable was the baseline assessment of food insecurity. We used a validated six-item scale, the short-form of the Food Security Survey Module created by the U.S. Department of Agriculture (12), to assess food insecurity during the year before the study. Participants were asked to respond to the following statements/questions about their household (affirmative responses are marked in bold):

1. The food that (I/we) bought just didn't last, and (I/we) didn't have money to get more. (**often, sometimes, or never true**)
2. (I/We) couldn't afford to eat balanced meals. (**often, sometimes, or never true**)
3. Did you or other adults in your household ever cut the size of your meals or skip meals because there wasn't enough money for food? (**yes, no**)
4. [IF YES to #3] How often did this happen? (**almost every month, some months but not every month, or in only 1 or 2 months**)
5. In the last 12 months, did you ever eat less than you felt you should because there wasn't enough money for food? (**yes, no**)
6. In the last 12 months, were you ever hungry but didn't eat because there wasn't enough money for food? (**yes, no**)

Using established conventions (13), we classified a total of two or more affirmative responses as food insecure.

Our primary outcome was HbA_{1c}, abstracted from the electronic medical record at two time points that represented the two clinic visits closest to baseline and follow-up. The first time point was up to 6 months before baseline enrollment, and the second time point was at least 6

months but up to 1 year after baseline. On average, there were 266 days (SD 60) between abstractions, and 95% of participants had at least one value. There was variation in baseline HbA_{1c} values across trial arms because the unit of randomization was the clinic rather than the patient.

Secondary outcomes included diabetes self-efficacy and fruit and vegetable intake over the course of the trial (baseline and one year), collected via self-reported survey responses at baseline and 1-year follow-up. Diabetes self-efficacy was measured with a validated eight-item scale (14) rating confidence in performing a variety of diabetes behaviors from "not at all sure" to "very sure." The summary self-efficacy score was calculated as an average of these items among those who answered at least three of the eight questions. Finally, we captured self-reported fruit and vegetable consumption from questions that assessed the total number of servings per day, using items from the Behavioral Risk Factor Surveillance System survey (15,16).

Covariates included patient age (in years); sex; annual household income (<\$10,000, \$10,000–\$14,999, and ≥\$15,000); education (less than high school, high school graduate, some college, or college graduate or more); employment status (currently working or not working); race (white, black, or other); and health literacy [adequate versus inadequate, measured by the Short Test of Functional Health Literacy in Adults (STOFHLA) (17)]. These all were self-reported in the baseline assessment.

Statistical analyses

We used χ^2 tests and two-sided *t* tests to examine food insecurity in relation to patient characteristics and the outcomes of interest at both baseline and follow-up, examining them as continuous and dichotomous variables (HbA_{1c} at a clinically relevant cutpoint of 9%, and self-efficacy and nutritional intake at the lowest quartile at baseline). We examined adjusted longitudinal associations between baseline food insecurity and outcomes of interest using linear regression models with generalized estimating equations. These models used robust SEs, clustering by respondent and adjusting for time point, age, sex, race, income, and intervention arm. We adjusted for arm rather than clinic because we expected this to drive differences across sites based on the randomization of the larger trial. We also

included an interaction between time and food insecurity to examine changes in outcomes over time by food security group. Only patients with complete data for all time points were included in the longitudinal analyses.

We conducted three sensitivity analyses. To examine whether our outcomes were consistent across intervention arms, we completed the HbA_{1c} analyses separately by arm. In addition, because of the substantial missing data for HbA_{1c}, we examined the influence of carrying forward the baseline HbA_{1c} values for all participants without a follow-up value. This conservative estimate assumed no change over time for those individuals with missing follow-up HbA_{1c} values. Finally, we assessed how changes in food security status may have impacted the results by conducting an analysis limited to those participants whose food security status remained consistent throughout the trial (i.e., did not switch from food insecure to secure or food secure to insecure).

RESULTS—The study sample was 63% women and 66% white, and 57% of individuals had an annual income of <\$15,000 (Table 1). In addition, 219 of 665 individuals (33% of the sample)

reported food insecurity at baseline, which mirrors national estimates among low-income individuals (2). Participants who were food insecure were younger, had lower annual household incomes, and were less likely to be college graduates or currently working. There were no differences in food security status across intervention arms. Those with higher income and education were more likely to have missing follow-up data for all outcomes, and men and white participants were also more likely to have missing follow-up data for self-efficacy and fruit/vegetable intake. There were no differences by food security status comparing those with versus without follow-up HbA_{1c} values.

In unadjusted comparisons, there were significant differences in our primary and secondary outcomes by food security status (Table 2). At baseline, participants who were food insecure had significantly higher HbA_{1c} values (primary outcome: 8.4% vs. 8.0%; *P* = 0.01), lower diabetes self-efficacy, and lower fruit and vegetable intake. After implementation of the diabetes self-management intervention, significant unadjusted differences remained between food insecure and food secure participants at follow-up for diabetes self-efficacy and vegetable intake.

In adjusted regression models (Table 3) examining our primary outcome of interest, participants who are food insecure, began the trial with 0.59% higher baseline HbA_{1c} values, on average, compared with participants who are food secure (*P* < 0.01). However, participants who were food insecure participants made significant improvement in glycemic control over the course of the trial: a 0.38% decrease (*P* = 0.01) compared with no change (0.01% decrease; *P* = 0.87) among participants who were food secure. As a result, there were no longer statistically significant differences in follow-up HbA_{1c} values between participants who were food insecure and food secure. Dichotomizing the HbA_{1c} values at 9% showed a similar pattern of significant improvement among participants who were food insecure [adjusted odds ratio of poor A1C control comparing food insecure with food secure at baseline: 2.15 (95% CI 1.23–2.77), decreasing to and odds ratio of 1.10 (0.60–2.01) at follow-up].

In these adjusted comparisons for secondary outcomes (Table 3), participants who were food insecure also started with lower baseline self-efficacy and marginally lower fruit intake, yet made statistically significant improvements in their diabetes self-efficacy (a 0.27-point increase) and fruit intake (0.20 serving increase). The group that was food secure also improved, but with smaller increases in their diabetes self-efficacy scores [0.12-point increase, a statistically smaller improvement compared with those who were food insecure (*P* for interaction <0.01)] and fruit intake (0.10 serving increase; *P* for interaction = 0.20). Neither group made significant changes in their vegetable intake. At follow-up, participants who were food insecure continued to have significantly lower diabetes self-efficacy and vegetable consumption, although the magnitude of the differences in self-efficacy scores between the groups was smaller than at baseline.

In our sensitivity analysis by trial arm, patterns were similar across the three intervention arms, albeit with more limited power to detect statistically significant changes in HbA_{1c} over time for participants who were food insecure (Table 4). Carrying forward baseline HbA_{1c} values for those 283 participants with missing follow-up data, participants who were food insecure continued to have a 0.21% decrease in HbA_{1c} over time (*P* = 0.02), whereas participants who were food secure had a nonsignificant

Table 1—Patient characteristics by food security status at baseline

Characteristics	Total (N = 665)	Food secure (n = 446)	Food insecure (n = 219)	P
Mean age (±SD)	54.8 (±11.2)	56.3 (±11.4)	51.8 (±10.1)	<0.001
Female	417 (63)	268 (61)	149 (66)	0.22
Education				
Less than high school	164 (25)	97 (22)	67 (30)	0.001
High school graduate	212 (32)	139 (32)	73 (32)	
Some college	199 (30)	128 (29)	71 (31)	
College graduate or higher	90 (14)	75 (17)	15 (7)	
Race				
Black	200 (30)	124 (29)	76 (34)	0.34
White	440 (66)	299 (68)	141 (63)	
Other	24 (4)	16 (4)	8 (4)	
Income (\$)				
<10,000	189 (29)	95 (22)	94 (42)	<0.001
10,000–15,000	180 (28)	106 (25)	74 (33)	
≥15,000	279 (43)	224 (53)	55 (25)	
Adequate health literacy	446 (67)	296 (67)	150 (66)	0.78
Smoking status				
Never	250 (38)	173 (40)	77 (34)	0.003
Former	231 (35)	163 (37)	68 (30)	
Current	182 (27)	102 (23)	80 (36)	
Employed	250 (38)	186 (43)	64 (29)	<0.001

Values provided as n (%) unless otherwise indicated.

Table 2—Unadjusted outcomes of interest by food insecurity status

Outcomes	Baseline (n = 665)			Follow-up (n = 473)		
	Food secure	Food insecure	P	Food secure	Food insecure	P
Glycemic control*						
Proportion with A1C \geq 9%	21%	32%	0.02	19%	22%	0.52
Mean HbA _{1c} (\pm SD)	8.0 (\pm1.8)	8.4 (\pm1.9)	0.01	7.8 (\pm 1.6)	8.1 (\pm 1.8)	0.14
Diabetes self-efficacy score						
Proportion with score \leq 3.25 (lowest quartile at baseline)	21%	47%	$<$ 0.001	15%	26%	0.004
Mean self-efficacy (\pm SD)	3.6 (\pm0.4)	3.3 (\pm0.5)	$<$ 0.001	3.7 (\pm0.4)	3.6 (\pm0.4)	0.02
Fruit servings per day						
Proportion with \leq 0.35 servings (lowest quartile at baseline)	20%	33%	$<$ 0.001	20%	25%	0.24
Mean servings of fruit (\pm SD)	1.1 (\pm0.8)	0.8 (\pm0.7)	$<$ 0.001	1.1 (\pm 0.9)	1.0 (\pm 0.8)	0.22
Vegetable servings per day						
Proportion with \leq 1.2 servings (lowest quartile at baseline)	22%	31%	0.02	23%	30%	0.09
Mean servings of vegetables (\pm SD)	2.1 (\pm1.2)	1.8 (\pm1.0)	$<$ 0.001	2.1 (\pm1.2)	1.8 (\pm0.9)	0.002

Bold indicates statistical significance. *At baseline, 630 patients had HbA_{1c} levels recorded; at follow-up, 356 patients had levels recorded.

decrease of 0.01%. Finally, we examined changes in food insecurity status over time: 38 of 473 respondents in the follow-up sample (8%) shifted from food secure to insecure over the course of the trial, and 49 (10%) went from food insecure to secure. Limiting the model to the 357 individuals who were consistent in their food security status over the course of the trial also did not substantively impact results (not shown).

CONCLUSIONS—Several previous cross-sectional analyses have found higher HbA_{1c} and/or lower diabetes

self-efficacy among adults who are food insecure and have diabetes (4,5,8), as well as somewhat mixed results for fruit and vegetable intake (10,18). We expand on this literature by examining changes in HbA_{1c} and self-efficacy over time. We found that participants who were food insecure began our study with poorer HbA_{1c} and self-efficacy scores, similar to patterns found in other observational studies. However, participants who were food insecure made improvements in these outcomes over time in the context of a diabetes educational intervention—changes that were often

greater in magnitude than those observed among participants who were food secure. Overall, our findings conflict with our initial hypothesis that individuals facing challenges in obtaining food because of financial hardship would be less able to engage in diabetes self-management interventions.

Our findings suggest that participants who are food insecure are able to engage in a diabetes education intervention that generally focuses on self-management strategies (including dietary changes) even though the intervention did not specifically address budget-related strategies for improving dietary intake. Although this study was a secondary analysis of a larger randomized trial targeting low-income patients with diabetes, the pattern of greater improvement in HbA_{1c} values for participants who were food insecure was also relatively robust across study arms, suggesting that the method, and perhaps even content, of the diabetes intervention is relatively less important than receiving some kind of self-management support. The diabetes guide and structured self-management support intervention provided to many patients was action oriented, patient centered, and literacy appropriate, which may have made it easy for low-income patients to understand and use to make relevant and feasible action plans. Future work is needed to understand how participants who are food insecure engage in such interventions, but it seems that patients who are food insecure may be able to draw on existing coping strategies to improve diabetes self-management even while maintaining severely constrained food budgets.

We are not aware of any other studies of food insecurity conducted in the context of a diabetes educational intervention. Other studies examining the effectiveness of diabetes interventions across socioeconomic status have not

Table 3—Adjusted comparisons at baseline and follow-up and changes within food security status groups (N = 453)

	Food insecure compared with food secure at baseline	Change among food secure participants	Change among food insecure participants	Food insecure compared with food secure at follow-up
HbA _{1c} (%)	0.59* (0.19 to 0.98)	−0.01 (−0.19 to 0.16)	−0.38* (−0.69 to −0.08)	0.22 (−0.16 to 0.60)
Diabetes self-efficacy score (0–4)	−0.23* (−0.33 to −0.13)	+0.12* (0.07 to 0.17)	+0.27* (0.19 to 0.35)	−0.08* (−0.16 to −0.01)
Daily servings of fruit	−0.12† (−0.26 to 0.01)	+0.10* (0.05 to 0.19)	+0.20* (0.07 to 0.33)	−0.01 (−0.17 to 0.16)
Daily servings of vegetables	−0.16 (−0.36 to 0.05)	+0.07 (−0.04 to 0.17)	−0.02 (−0.20 to 0.11)	−0.27* (−0.47 to −0.07)

Values provided as β (95% CI). All 5 generalized estimating equation models adjusted for age, sex, income, race, intervention arm, time, and interaction between food insecurity and time; n = 339 for adjusted A1C model. Bold indicates statistical significance. *P < 0.05; †P < 0.10.

Table 4—Adjusted changes in HbA_{1c} by intervention arm

Intervention arm	Food insecure compared with			Food insecure compared with food secure at follow-up
	food secure at baseline	Change for food secure	Change for food insecure	
Carve-in only (n = 110)	0.98* (0.40 to 1.53)	+0.10 (−0.21 to 0.41)	−0.42 (−0.95 to 0.10)	0.46 (−0.13 to 1.05)
Carve-out only (n = 122)	0.20 (−0.35 to 0.76)	+0.06 (−0.20 to 0.32)	−0.27 (−0.77 to 0.22)	−0.13 (0.72 to 0.46)
Off-protocol only (n = 107)	0.79† (−0.08 to 1.67)	−0.20 (−0.55 to 0.15)	−0.48 (−1.08 to 0.11)	0.51 (−0.28 to 1.31)

Values provided as β (95% CI). Generalized estimating equation models adjusted for age, sex, income, race, time, and interaction between food insecurity and time. Bold indicates statistical significance. * $P < 0.05$, † $P < 0.10$.

reported significant differences. For example, the GOAL Lifestyle Implementation Trial found similar improvements in clinical outcomes as well as self-efficacy and planning across education levels (19,20). In addition, the Diabetes Prevention Program trial reported no differences in achieving physical activity or weight loss goals across income levels (21).

Although we examined each outcome (HbA_{1c}, diabetes, dietary self-efficacy, fruit and vegetable intake) independently in this analysis, we expect that they are related to one another. For example, other studies have shown that self-efficacy is strongly associated with fruit and vegetable intake and HbA_{1c} (22,23). Future interventions targeted to low-income patients with diabetes might benefit by explicitly examining food insecurity as an exposure of interest as well as by examining the interplay of self-efficacy, nutrition, and intermediate clinical outcomes by food security status. In addition, although a smaller number of participants changed food security status over the course of the trial (18% of the total sample), future studies should also consider the variable nature of food security among low-income populations. Moreover, examining these associations in relation to social support and depression may be particularly important (24).

This study has several limitations. First, because participants who were food insecure started the trial with poorer values for the outcome measures, regression to the mean may partially explain our findings. Because multiple other cross-sectional studies have suggested that HbA_{1c} values are higher in participants who are food insecure across different samples and points in time (3–7), we would not expect improved HbA_{1c} levels to be a temporal trend among those who are food insecure without the support of a self-management intervention. However, because this was an observational study of changes over time (conducted within a larger trial), we cannot conclusively state

that the intervention activities themselves were more effective for the participants who were food insecure compared with those who were food secure. Furthermore, our measure of fruit and vegetable intake was not captured using the gold standard of 24-h recall, which may have impacted our ability to examine more accurate changes in nutritional intake over time. Our findings may also not be generalizable to other populations. Finally, missing data for some outcome values could have biased study results; however, a sensitivity analysis carrying forward baseline values still found significant decreases in HbA_{1c} for participants who were food insecure compared with those who were food secure.

With increasing awareness of food insecurity in clinical settings, our study has particular relevance for health care providers treating low-income patients with diabetes. Our findings suggest that targeted self-management support can be effective in improving glycemic control, even among subgroups of patients facing structural socioeconomic barriers such as food insecurity. Therefore, providers should not assume that patients who are food insecure will be unable to improve their diabetes-related or even dietary behaviors because of barriers such as limited ability to afford diabetes-appropriate foods. This population is noted to have diverse and highly effective coping strategies (25,26), which may be drawn on in the setting of educational support for diabetes self-management. Future research should address whether multipronged interventions targeting both diabetes self-management skills and food insecurity act synergistically to improve glycemic control and reduce diabetes complications.

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C.R.L. conceptualized and completed the analyses and wrote the manuscript. M.S.W., D.S., T.C.D., D.D., and H.K.S. designed the trial, provided conceptualization and supervision of this study, and reviewed/edited the manuscript. A.R.D. and L.C. provided research support for the trial, assisted with study analyses, and edited the manuscript. C.R.L. is the guarantor of this work and, as such, had full access to all the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.

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