Diabetes-Specific Food Insecurity Is Associated with Impaired Heart Rate Variability Independent of Glycemic Control: Exploratory Findings among Latinos with Type 2 Diabetes[1,2]

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Abstract

Background: Food insecurity (FI), diabetes prevalence, and poor diabetes outcomes all disproportionately affect Latinos in the United States. Heart rate variability (HRV) reflects autonomic tone, is associated with glycemic control, and predicts mortality in type 2 diabetes. It is unknown whether FI is related to HRV and, if so, whether glycemic control accounts for this association.

Objective: This exploratory cross-sectional study examined FI and HRV among US Latinos with type 2 diabetes.

Methods: Participants reported demographic characteristics, socioeconomic status, and FI, including the 6-item USDA food security module and a 1-item measure of diabetes-specific food security. Participants wore an ambulatory electrocardiogram monitor for 24 h. In the time domain, HRV was assessed with the SD of the R-R interval (SDNN). In the frequency domain, the power spectrum was integrated over 3 frequency bands—very low frequency (VLF), low frequency (LF), and high frequency (HF)—and then natural log transformed. Unadjusted ANOVA and ANCOVA adjusted for age, sex, glycated hemoglobin (HbA1c), and indicators of socioeconomic status compared food security groups on HRV.

Results: Participants' mean ± SD age was 59.7 ± 10.9 y, and 73% were women. Of the 94 participants, 63 reported FI according to the USDA food security module and 46 reported FI according to the diabetes-specific measure. Mean ± SD HbA1c was 8.6% ± 1.7% and was marginally higher among those reporting diabetes-specific FI than those reporting diabetes-specific food security. Participants who reported diabetes-specific FI had lower SDNN, VLF, LF, and HF HRV with effect sizes in the small-to-medium range. Differences remained significant even after controlling for age, sex, socioeconomic hardship, and HbA1c. The 6-item USDA food security module was not associated with HRV.

Conclusions: Diabetes-specific FI may be a unique risk factor for poor health outcomes among US Latinos. Efforts to address FI could benefit diabetes outcomes. *Curr Dev Nutr* 2017;1:e000521.

Introduction

Food insecurity (FI)[9] is the limited or uncertain ability to acquire nutritionally adequate and safe foods (1). FI is associated with increased risk of type 2 diabetes (T2D) (2), and among persons with diabetes, it is associated with poor glycemic control (3). In 2015, 12.7% of US households (15.8 million households) were food insecure, and the prevalence was higher for Latino households (19.1%) than for non-Hispanic white households (10.0%) (4).

Keywords: food insecurity, poverty, heart rate variability, type 2 diabetes, Latinos

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[9] Abbreviations used: CALMS-D, Community Health Educators Assisting Latinos Manage Stress and Diabetes; FI, food insecurity; HbA1c, glycated hemoglobin; HF, high frequency; HRV, heart rate variability; LF, low frequency; SDNN, SD of the R-R interval; T2D, type 2 diabetes; VLF, very low frequency.

Prospective studies have shown that FI hastens mortality in the general population and among medically compromised persons in North America (5, 6).

The mechanisms through which FI hastens mortality are unknown. Heart rate variability (HRV) is one putative mechanism. HRV quantifies the beat-to-beat changes in heart rate caused by changes in autonomic activity and reflects autonomic tone. Low HRV is an early finding in diabetic cardiac autonomic neuropathy (7) and may be present as early as at diabetes diagnosis (8). Poor glycemic control is associated with lower HRV (9). Low HRV is a strong predictor of mortality in the setting of diabetes (10).

Patients with diabetes are asked to follow specific nutritional guidelines. Patients may have food security (i.e., access to nutritionally adequate and safe foods), yet still be financially unable to select the types of foods recommended for their diabetes management. Several validated scales are used to measure FI, most of which largely measure the ability to acquire enough food (11, 12). That is, they assess food security as it pertains to food quantity. Although the commonly used 6-item USDA scale does make reference to the ability to acquire "the types of foods desired," it does not reference the ability to acquire the healthy foods typically recommended for diabetes management (e.g., high-fiber, low-fat foods such as whole grains and vegetables). The objective of this exploratory cross-sectional analysis among low-income Latinos with T2D was to examine the relations among the 6-item USDA food security module, diabetes-specific FI, and HRV and to determine whether glycemic control accounts for any association.

Methods

We analyzed cross-sectional baseline data from the Community Health Educators Assisting Latinos Manage Stress and Diabetes (CALMS-D) trial, which is registered at clinicaltrials.gov as NCT01578096 (13, 14). Participants were recruited from an inner-city clinic if they were adult residents of Hartford, Connecticut; Latino/Hispanic and Spanish-speaking; had T2D for ≥6 mo; and had glycated hemoglobin (HbA1c) concentrations ≥7.0%. Patients were excluded for the following reasons: medical instability or intensive medical treatment, bipolar disorder or thought disorder, suicide attempt or psychiatric hospitalization in the past 2 y, alcohol problems, or enrollment in another research study.

The CALMS-D trial was approved by the institutional review boards involved, and all participants provided written informed consent. At a morning home visit, participants provided informed consent, provided a fasting venous blood sample, answered questionnaires that were verbally administered by interviewers in their preferred language (English or Spanish), and were compensated $10. Next, participants were instrumented with 7-lead, 3-channel ambulatory electrocardiogram monitors, i.e., holter monitors [GE Medical Marquette Series 8500 direct (amplitude-modulated) recorders]. Participants were de-instrumented after 24 h.

Measures

FI. We measured diabetes-specific FI with the question, "In the past year, has it happened to you that you did not have enough money to buy the food you should eat for your diabetes?" We defined a "yes" response as diabetes-specific FI and a "no" response as diabetes-specific food security. This question was designed specifically for this study. The English and Spanish CALMS-D survey questions were piloted and revised in an iterative fashion with the target community. The final questions showed excellent content and face validity as previously reported (13).

We also measured FI with the use of the 6-item USDA food security module (15, 16). A raw score of 0–1 indicates high or marginal food security, 2–4 indicates low food security, and 5–6 indicates very low food security. We also used scores of 0 compared with >0 to dichotomize participants as either food secure or food insecure (17). Finally, we also calculated a total sum score for a continuous measure of food security.

HRV. HRV was assessed as in our previous studies (18). Holter recordings were scanned by an experienced technician. As described in the literature (19), each tape was manually processed and edited and then analyzed with customized software. The R-R interval data file was edited to remove ectopics and noise, and gaps were filled in by interpolated linear splines. In the time domain, we assessed the SD of each normal-to-normal beat (SDNN; i.e., each normal R-R interval). The power spectrum was computed by using a fast Fourier transform with a Parzen window and corrected for attenuation due to windowing and sampling. The power spectrum was integrated over 3 frequency bands (19): very low frequency (VLF; 0.0033 to <0.04 Hz), low frequency (LF; 0.04 to <0.15 Hz), and high frequency (HF; 0.15–0.40 Hz). As expected, HRV values in the frequency domain were non-normal and so were ln transformed (20).

Covariates

Age and sex were provided per self-report. HbA1c was assayed from venous blood samples in the University of Connecticut clinical laboratory by using HPLC. To isolate the effect of FI from other sources of economic hardship, we controlled for socioeconomic indicators, including educational attainment (high school graduate or General Educational Development or less than high school graduate or General Educational Development), and total monthly household income including government assistance. We also controlled for self-reported financial strain over the past 12 mo on a scale from 1 = "We have enough and can save" to 4 = "We don't have enough and we have great difficulties" (21).

Data analysis

Data were analyzed by using SPSS version 21. ANOVA was used to detect unadjusted differences in HRV indexes between FI groups, and ANCOVA was used for the same analyses adjusted for covariates. Partial η^2 values were calculated for each ANOVA as an indicator of effect size. Multiple linear regression was performed to examine the relation between continuous FI scores and HRV indexes; α was set at 0.05.

Results

A total of 121 individuals participated in baseline assessments for the CALMS-D trial. Of those, n = 11 did not have HRV data, data from

$n = 15$ required >20% interpolation and so were excluded from analysis, and 1 individual did not provide food security data. This yielded a final $n = 94$ for analysis (see **Table 1** for participant characteristics by diabetes-specific food security status).

By using our diabetes-specific food security item, 48 reported diabetes-specific food security and 46 reported diabetes-specific FI. With the use of the USDA 6-item food security module, 31 participants were food secure and 63 were food insecure. HRV values were substantially lower than reported for a healthy middle-aged sample (SDNN = 96 compared with 141) (19). HRV values were also substantially lower in the diabetes-specific food insecure group compared with the diabetes-specific food secure group (Table 1).

With the use of ANOVA, participants who reported diabetes-specific FI had lower SDNN, ln-VLF, ln-LF, and ln-HF than did participants who reported diabetes-specific food security. With the use of ANCOVA, when covariates were added to the model, results for SDNN, ln-VLF, and ln-LF remained significant (all $P < 0.05$). Results for ln-HF remained significant with all demographic and socioeconomic covariates but were reduced to $P = 0.06$ with the inclusion of HbA1c, although HbA1c was not a significant predictor of ln-HF. HbA1c was a significant predictor of ln-VLF and ln-LF. Results indicated partial η^2 values ranging from 0.05 for SDNN and VLF to 0.06 for LF and HF, each of which indicates a small-to-medium effect size for the association between diabetes-related FI and HRV.

With ANOVA, the use of the USDA 6-item food security module to classify participants as having high or marginal food security, low food security, or very low food security, food security status was not associated with any HRV index (all $P > 0.20$). With the use of the USDA 6-item food security module to dichotomize participants as food secure or food insecure, food security status was not associated with any HRV index (all $P > 0.30$). In regression analysis, the use of the total sum score on the USDA 6-item food security model score was not associated with any HRV index (all $P > 0.44$).

Discussion

The main finding from this exploratory study is that among low-income Latinos with T2D, individuals who reported diabetes-specific FI had lower HRV than individuals who reported diabetes-specific food security. Specifically, individuals who cannot afford to buy the foods that they believe are necessary for diabetes self-management had lower HRV. Our findings also suggest that

TABLE 1 Participant characteristics by diabetes-specific food security status[1]

Characteristic	Total ($n = 94$)	Diabetes-specific food secure ($n = 48$)	Diabetes-specific food insecure ($n = 46$)	*P*
Age, y	59.70 ± 10.90	61.98 ± 10.59	57.37 ± 10.81	0.041*
Sex, *n* (%)				0.026*
Female	69 (73)	40 (83)	29 (63)	
Marital status, *n* (%)				0.659
Single	64 (68)	34 (71)	30 (65)	
Language spoken, *n* (%)				0.541
English and Spanish	52 (55)	25 (52)	27 (59)	
Spanish only	42 (45)	23 (48)	19 (41)	
Years in United States	35.80 ± 14.39	36.72 ± 15.27	34.85 ± 13.54	0.533
Employment status, *n* (%)				0.325
Employed	0 (0)	0 (0)	0 (0)	
Unemployed looking for work	15 (16)	5 (10)	10 (22)	
Unemployed not looking	26 (28)	14 (29)	12 (26)	
Disabled	53 (56)	29 (60)	24 (52)	
Educational attainment, *n* (%)				0.359
Less than high school	68 (72)	37 (77)	31 (67)	
Monthly household income, *n* (%)				0.176
$0–$1000	63 (67)	37 (77)	26 (57)	
$1001–$1500	26 (28)	8 (17)	18 (39)	
$1501–$2000	2 (2)	1 (2)	1 (2)	
$2001–$3000	3 (3)	2 (4)	1 (2)	
>$3000	0 (0)	0 (0)	0 (0)	
Financial strain[2]	2.53 ± 0.84	2.21 ± 0.74	2.87 ± 0.81	0.000*
HbA1c				
mmol/mol (IFCC)	70.06 ± 18.49	66.73 ± 18.20	73.47 ± 18.35	0.079
% (NGSP)	8.56 ± 1.69	8.26 ± 1.67	8.87 ± 1.68	0.079
SDNN	95.80 ± 28.16	102.12 ± 24.15	89.35 ± 30.67	0.028*
ln-VLF	6.44 ± 0.84	6.64 ± 0.77	6.24 ± 0.86	0.022*
ln-LF	5.31 ± 1.02	5.56 ± 1.00	5.05 ± 1.03	0.014*
ln-HF	4.53 ± 1.11	4.78 ± 1.11	4.28 ± 1.06	0.028*

[1] Values are means ± SDs unless otherwise indicated. Chi-square tests were performed to examine differences in food insecurity status on categorical variables, and *t* tests were performed for continuous variables. All heart-rate variability values corresponding to SDNN, ln-VLF, ln-LF, and ln-HF are unadjusted. *$P < 0.05$. HbA1c, glycated hemoglobin; IFCC, International Federation of Clinical Chemistry; ln-HF, natural log–transformed high frequency; ln-LF, natural log–transformed low frequency; ln-VLF, natural log–transformed very low frequency; NGSP, National Glycohemoglobin Standardization Program; SDNN, SD of the R-R interval.

[2] Financial strain was measured on a 4-point Likert scale from 1 = "We have enough and can save" to 4 = "We don't have enough and we have great difficulties."

diabetes-specific FI is associated with HRV through mechanisms other than, or in addition to, glycemic control. Whereas FI worsens glycemic control, and glycemic control worsens HRV, the link between FI and HRV is not solely due to glycemic control. Furthermore, diabetes-specific FI was related to HRV independently of common socioeconomic indicators. This implies that diabetes-specific FI uniquely exerts deleterious effects on the autonomic system above and beyond commonly accepted poverty proxies. To our knowledge, these are the first data linking FI with HRV.

Previous work has shown that social adversity is related to lower HRV. This includes racial minority status, social class, cumulative life stress (22), and poverty (23). Yet, here we show that even among minorities of low socioeconomic status, diabetes-specific FI exerts a unique effect on HRV above and beyond other socioeconomic stressors.

Several studies have shown that low HRV is predictive of early mortality, even after controlling for other risk factors. In the Framingham Heart Study, a 1-SD difference in the ln-LF power nearly doubled the risk of all-cause mortality (24). Similar findings have been reported in other studies and appear to be especially strong among persons with diabetes (10). Thus, our findings have important implications for diabetes-related health outcomes. Although we were limited by a cross-sectional design and we were unable to follow the sample for mortality, our findings might suggest that HRV is one mechanism through which FI increases the risk of early mortality. Limitations include secondary data analysis, a cross-sectional design, small sample, and a subjective measure of diabetes-specific FI. Putative mediators such as nutritional composition, energy intake, and psychological distress should be tested to understand the various potential mechanisms through which diabetes-specific FI may impair autonomic function. These limitations are generally outweighed by the study's strengths, which include a hard-to-reach clinical sample, state-of-the-art HRV assessment, and a novel, simple, and clinically relevant research question.

In conclusion, participants who reported diabetes-specific FI had lower HRV than those who reported diabetes-specific food security. If these exploratory findings are replicated, efforts to end, decrease, or mitigate the effects of FI could have beneficial effects on diabetes outcomes.

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References

1. Anderson SE. Core indicators of nutritional state for difficult-to-sample populations. J Nutr 1990;120:1559–600.
2. Fitzgerald N, Hromi-Fiedler A, Segura-Perez S, Perez-Escamilla R. Food insecurity is related to increased risk of type 2 diabetes among Latinas. Ethn Dis 2011;21:328–34.
3. Seligman HK, Jacobs EA, Lopez A, Tschann J, Fernandez A. Food insecurity and glycemic control among low-income patients with type 2 diabetes. Diabetes Care 2012;35:233–8.
4. Coleman-Jensen A, Rabbitt M, Gregory C, Singh A. Household food security in the United States in 2015. Washington (DC): USDA, Economic Research Service; 2016. Report No.: ERR-215.
5. Weiser SD, Fernandes KA, Brandson EK, Lima VD, Anema A, Bangsberg DR, Montaner JS, Hogg RS. The association between food insecurity and mortality among HIV-infected individuals on HAART. J Acquir Immune Defic Syndr 2009;52:342–9.
6. Gundersen C, Tarasuk V, Cheng J, de Oliveira C, Kurdyak P, Dachner N. Food insecurity status and mortality in Ontario, Canada. FASEB J 2016;30(1 Suppl):S273–5.
7. Vinik AI, Maser RE, Mitchell BD, Freeman R. Diabetic autonomic neuropathy. Diabetes Care 2003;26:1553–79.
8. Ratzmann KP, Raschke M, Gander I, Schimke E. Prevalence of peripheral and autonomic neuropathy in newly diagnosed type II (noninsulin-dependent) diabetes. J Diabet Complications 1991;5:1–5.
9. Meyer ML, Gotman NM, Soliman EZ, Whitsel EA, Arens R, Cai J, Daviglus ML, Denes P, González HM, Moreiras J, et al. Association of glucose homeostasis measures with heart rate variability among Hispanic/Latino adults without diabetes: the Hispanic Community Health Study/Study of Latinos (HCHS/SOL). Cardiovasc Diabetol 2016; 15:45.
10. Gerritsen J, Dekker JM, TenVoorde BJ, Kostense PJ, Heine RJ, Bouter LM, Heethaar RM, Stehouwer C. Impaired autonomic function is associated with increased mortality, especially in subjects with diabetes, hypertension, or a history of cardiovascular disease: the Hoorn study. Diabetes Care 2001;24:1793–8.
11. Harrison GG, Stormer A, Herman DR, Winham DM. Development of a Spanish-language version of the U.S. household food security survey module. J Nutr 2003;133:1192–7.
12. Villagómez-Ornelas P, Hernandez-Lopez P, Carrasco-Enriquez B, Barrios-Sanchez K, Perez-Escamilla R, Melgar-Quinonez H. [Statistical validity of the Mexican Food Security Scale and the Latin American and Caribbean Food Security Scale.] Salud Publica Mex 2014;56(Suppl 1):s5–11 (in Spanish).
13. Wagner J, Bermudez-Millan A, Damio G, Segura-Perez S, Chhabra J, Vergara C, Perez-Escamilla R. Community Health Workers Assisting Latinos Manage Stress and Diabetes (CALMS-D): rationale, intervention design, implementation, and process outcomes. Transl Behav Med 2015;5:415–24.
14. Wagner JA, Bermudez-Millan A, Damio G, Segura-Perez S, Chhabra J, Vergara C, Perez-Escamilla R. A randomized, controlled trial of a stress management intervention for Latinos with type 2 diabetes delivered by community health workers: outcomes for psychological wellbeing, glycemic control, and cortisol. Diabetes Res Clin Pract 2016; 120:162–70.
15. Bickel G, Nord M, Price C, Hamilton W, Cook J. Guide to measuring household food security. Revised 2000. Alexandria (VA): USDA, Food and Nutrition Service; 2000.
16. Blumberg SJ, Bialostosky K, Hamilton WL, Briefel RR. The effectiveness of a short form of the Household Food Security Scale. Am J Public Health 1999;89:1231–4.
17. Cook JT, Black M, Chilton M, Cutts D, Ettinger de Cuba S, Heeren TC, Rose-Jacobs R, Sandel M, Casey PH, Coleman S, et al. Are food insecurity's health impacts underestimated in the U.S. population? Marginal food security also predicts adverse health outcomes in young U.S. children and mothers. Adv Nutr 2013;4:51–61.
18. Lampert R, Ickovics J, Horwitz R, Lee F. Depressed autonomic nervous system function in African Americans and individuals of lower social class: a potential mechanism of race- and class-related disparities in health outcomes. Am Heart J 2005;150:153–60.
19. Bigger JT Jr., Fleiss JL, Steinman RC, Rolnitzky LM, Kleiger RE, Rottman JN. Frequency domain measures of heart period variability and mortality after myocardial infarction. Circulation 1992;85:164–71.

20. Nunan D, Sandercock GR, Brodie DA. A quantitative systematic review of normal values for short-term heart rate variability in healthy adults. Pacing Clin Electrophysiol 2010;33:1407–17.
21. Parás P, Pérez-Escamilla R. El rostro de la pobreza: la inseguridad alimentaria en el Distrito Federal. [The face of poverty: food insecurity in the Federal District.] Rev Este País 2004;158:45–50 (in Spanish).
22. Lampert R, Tuit K, Hong KI, Donovan T, Lee F, Sinha R. Cumulative stress and autonomic dysregulation in a community sample. Stress 2016; 19:269–79.
23. Wagner J, Keuky L, Lampert R, Fraser-King L, Feinn R, Kuoch T, Scully M. Socioeconomic status, waist-to-hip ratio, and short-term heart rate variability in Cambodians with type 2 diabetes. Int J Behav Med 2015;22:786–91.
24. Tsuji H, Venditti FJ Jr., Manders ES, Evans JC, Larson MG, Feldman CL, Levy D. Reduced heart rate variability and mortality risk in an elderly cohort: the Framingham Heart Study. Circulation 1994;90:878–83.