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Diabetes Research
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Diabetes
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Associations between food insecurity and prediabetes in a representative sample of U.S. Adults (NHANES 2005–2014) [☆]

Lauri Wright ^{a,*}, Sericea Stallings-Smith ^b, Andrea Y. Arikawa ^a^a Department of Nutrition and Dietetics, University of North Florida, 1 UNF Drive, Jacksonville, FL 32224, USA^b Department of Public Health, University of North Florida, 1 UNF Drive, Jacksonville, FL 32224, USA

ARTICLE INFO

Article history:

Received 11 July 2018

Received in revised form

6 November 2018

Accepted 23 November 2018

Available online 27 November 2018

Keywords:

Food insecurity

NHANES

Prediabetes

Cross-sectional

ABSTRACT

Aims: The primary aim of this research was to investigate the association between food insecurity and prediabetes and to identify specific subgroups for early clinical intervention. **Methods:** Cross-sectional data from 25,814 participants were analyzed from the National Health and Nutrition Examination Survey for years 2005–2014. Multivariable logistic regression was used to explore the association between food security status and laboratory-confirmed prediabetes. All models were adjusted for age, sex, race, and body mass index. **Results:** When compared to participants with full and marginal food security, participants with low/very food security were 1.35 (95% CI: 1.17–1.55) times more likely to have prediabetes. Younger individuals with low/very low food security had a greater likelihood of prediabetes, 1.50 (95% CI: 1.19–1.81), when compared with their food secure counterparts. **Conclusions:** Food insecurity at any level, whether low or very low, is positively associated with prediabetes in the U.S. general adult population. Food insecure young adults, particularly those aged 20–34 years, should be targeted for early clinical intervention.

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1. Introduction

It is estimated that 84 million people, at least a third of the nation's adult population, are living with prediabetes while 90% of those with prediabetes are not aware of their condition [1]. Prediabetes increases the risk of developing type 2 diabetes mellitus (T2DM) as well as heart disease and stroke. T2DM results in significant disability, premature mortality, and substantial health care costs [2]. Significant predictors for prediabetes are age, sex, family history of diabetes mellitus, and body mass index [3].

Food insecurity is increasingly being recognized as a major public health issue [4–6]. In 2016, 12.3% or 15.6 million U.S. households experienced food insecurity [5]. Food insecurity is defined as limited access to a sufficient quantity of affordable, nutritious food. Risk for food insecurity is higher among households headed by Hispanics, Non-Hispanic Blacks, and single mothers with children [5].

Multiple studies have demonstrated an association between food insecurity and numerous health issues such as obesity, diabetes, heart disease, hypertension, depression, and anxiety [7–10]. The underlying biological mechanisms

[☆] This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

* Corresponding author.

E-mail address: l.wright@unf.edu (L. Wright).

<https://doi.org/10.1016/j.diabres.2018.11.017>

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and pathways by which food insecurity influences health are not well understood. However, there are factors that may contribute to the positive association between food insecurity and insulin resistance. First, multiple studies have found greater obesity among those who are food insecure [7], which may increase the risk for prediabetes and diabetes. This contradictory relationship is now referred to as the hunger-obesity paradox. Second, a common coping strategy among food insecure individuals is to purchase inexpensive, energy-dense foods because of their lower cost [11], often resulting in a greater intake of refined carbohydrates, fat, and decreased intake of fruits, vegetables, and fiber [12]. This dietary pattern, in turn, is associated with insulin resistance and T2DM [13,14]. An additional coping strategy seen in food insecurity is binge-like eating when food becomes available [15], a pattern also associated with insulin resistance and obesity [9]. Finally, food insecurity may influence inflammatory pathways associated with insulin resistance due to psychosocial strain or inadequate diet quality [16].

Because food insecurity impacts diabetes self-management, the American Diabetes Association Standards of Care stated in 2016 that providers should “evaluate hyperglycemia and hypoglycemia in the context of food insecurity and propose solutions accordingly.” The progression from prediabetes to T2DM occurs over many years and there is strong evidence to support intervention to delay the progression from prediabetes to diabetes. Therefore, early detection of prediabetes and intervention is critical. While food insecurity has been clearly associated with diabetes, little is known about the prediabetes and food insecurity. The purpose of this research is to investigate the association between food insecurity and prediabetes and to identify specific subgroups for early clinical intervention.

2. Materials and methods

2.1. Data source

National Health and Nutrition Examination Survey (NHANES) data for adults aged ≥ 20 years were analyzed for years 2005–2014 [17]. The exposure of interest was adult food security category measured through personal interviews conducted by NHANES representatives. Food security categories were scored based upon the number of affirmative responses to ten items, which included queries such as “Were you ever hungry but didn’t eat because you couldn’t afford enough food?”. The outcome of interest was prediabetes defined as laboratory-confirmed glycohemoglobin levels (HbA1c) between 5.7% and 6.4%. Information for the potential confounders of age, sex, and race were collected by NHANES representatives via self-reported questionnaire. Body mass index (BMI) was obtained in an NHANES Mobile Examination Center (MEC).

2.2. Potential confounders

Factors were considered to be potential confounders if they affect both the exposure and the outcome [18]. As such, statistical adjustments were conducted for age as a continuous

variable and sex as a dichotomous variable. Since being a racial minority is associated with both the exposure [19] and the outcome [20], race was included as a nominal variable, categorized as Non-Hispanic White, Non-Hispanic Black, Mexican American and Other Hispanic, and Other Race, including Multi-Racial. In addition, BMI has been shown to be associated with both food security status [21] and prediabetes [20]; therefore, models were statistically adjusted for BMI as a continuous variable.

2.3. Statistical analyses

The NHANES exposure variable for food security was categorized as “Full Food Security” for participants with an adult food security score of zero, “Marginal Food Security” for participants with an adult food security score of 1–2, “Low Food Security” for participants with an adult food security score of 3–5, and “Very Low Food Security” for participants with an adult food security score of 6–10. To conduct statistical analyses, the reference group was designated as a combined variable of the “Full Food Security” and “Marginal Food Security” categories. The prediabetes outcome was coded dichotomously as a yes/no variable.

Multivariable logistic regression was conducted to investigate the association between food security levels and the outcome of prediabetes, accounting for potential confounding factors and stratifying by demographic variables. The primary analyses explored the association between any level of food insecurity (i.e. low and very low food security as a combined variable) and prediabetes. Secondary analyses investigated whether there was a dose response in the likelihood of prediabetes when food security status shifted from low to very low food security. A sensitivity analyses was conducted with the reference group designated as “Full Food Security” with comparisons to “Marginal Food Security” and “Low/Very Low Food Security” for the prediabetes outcome. For all analyses, odds ratios (OR) and 95% confidence intervals (CI) were calculated to determine the relative odds of the occurrence of prediabetes among participants in the reference group (i.e. either full food security or full/marginal food security) and participants with lesser food security status. In addition, these estimates represent the relative magnitude of difference between the demographic subgroups within categories of food security status.

Stratified analyses were also conducted by BMI, wherein participants were grouped into the following categories: “Normal Weight” for participants with a BMI of 18.5 kg/m² to 24.9 kg/m², “Overweight” for participants with a BMI of 25.0 kg/m² to 29.9 kg/m², and “Obese” for participants with a BMI ≥ 30.0 kg/m². There were insufficient observations to create an individual category for those who were underweight; however, a sensitivity analysis was conducted with the inclusion of underweight participants in the normal weight category (BMI ≤ 24.9 kg/m²).

All analyses were conducted with SAS 9.4 statistical software. Statistical modeling was carried out with the SAS SURVEYLOGISTIC procedure, allowing the inclusion of statistical weights for the NHANES sample to address the differential likelihood of participant selection, non-coverage, and non-response. More specifically, 10-year MEC survey weights were

allocated to all models to account for the inclusion of five NHANES survey cycles. Weights were then normalized across all data years from 2005 to 2014. The Taylor Series Linearization method was used for variance estimation, which is the recommended method of analysis by the National Center for Health Statistics (NCHS) for all NHANES surveys [22].

3. Results

The characteristics of the study population, including age, sex, race, body mass index, food security score and laboratory-confirmed prediabetes are shown in Table 1. Our study population consisted of 25,814 adults aged ≥ 20 years with available information on both food security status and glycohemoglobin levels.

Overall, when compared to participants with full and marginal food security, participants with low/very low food security were 1.35 (95% CI: 1.17–1.55) times more likely to have prediabetes (Table 2). When stratified by age, individuals in the younger age groups with low/very low food security were more likely to have prediabetes than individuals with full or marginal food security. More specifically, the odds of prediabetes among participants ages 20–34 years were 1.50 (95% CI: 1.19–1.91) times greater than among participants the same age with full/marginal food security. Likewise, odds of prediabetes were 1.42 (95% CI: 1.12–1.79) and 1.45 (95% CI: 1.15–1.83) times higher among low/very low food secure participants ages 35–44 years and ages 45–54 years, respectively,

when compared to their food secure counterparts. Table 2 indicates that both males and females with low/very low food security were more likely to have prediabetes than their food secure counterparts. Non-Hispanic Whites and Mexican American/Other Hispanic participants with low/very low food security had a greater likelihood of prediabetes when compared to those with full/marginal food security. Individuals with low/very low food security had increased odds of prediabetes across all BMI categories when compared to individuals with full/marginal food security.

Secondary analyses indicated that there was largely no dose-response in estimates of association with prediabetes by decreasing levels of food security (Table 3). Moreover, food insecurity at any level was associated with similar odds of prediabetes across demographic groups. When stratified by age, individuals in the younger age groups with low food security were 1.31 (95% CI: 1.03–1.67) times more likely to have prediabetes than individuals with full or marginal food security, while younger individuals with very low food security were 1.78 (95% CI: 1.28–2.47) times more likely to have prediabetes than individuals with full or marginal food security.

Very low food security was positively associated with prediabetes among individuals who were overweight. In a sensitivity analysis including underweight study participants with normal weight study participants, a positive association with prediabetes was observed when comparing participants with low food security to those with full and marginal food

Table 1 – Characteristics of the study population, ages ≥ 20 years in the National Health and Nutrition Examination Survey (NHANES), 2005–2014.

Characteristic	n	Weighted %
Total	25,814	100
Age		
20–34 years	6634	27.2
35–44 years	4462	19.0
45–54 years	4422	20.2
55–64 years	4196	15.9
≥ 65 years	6100	17.7
Sex		
Female	13,316	52.0
Male	12,498	48.0
Race		
Non-hispanic white	11,795	68.9
Non-hispanic black	5350	10.9
Mexican American and other hispanic	6357	13.4
Other race, including multi-racial	2312	6.8
Body mass index*		
Underweight (<18.5 kg/m ²)	419	1.6
Normal weight (18.5–24.9 kg/m ²)	7139	29.4
Overweight (25.0–29.9 kg/m ²)	8529	33.6
Obese (≥ 30.0 kg/m ²)	9386	35.4
Adult food security score		
Full food security: 0	18,542	78.8
Marginal food security: 1–2	2867	8.7
Low food security: 3–5	2590	7.3
Very low food security: 6–10	1815	5.2
Laboratory-confirmed prediabetes		
Yes	6865	22.4
No	18,949	77.6

* Body mass index not available for 341 participants.

Table 2 – Adjusted Odds Ratios (aOR) for the association between food insecurity and laboratory-confirmed prediabetes, ages ≥ 20 years in the National Health and Nutrition Examination Survey (NHANES), 2005–2014.

Characteristic	Prediabetes aOR (95% CI)	
	Full/marginal food security	Low/very low food security
Overall	1.00	1.35 (1.17–1.55)
Age		
20–34 years	1.00	1.50 (1.19–1.91)
35–44 years	1.00	1.42 (1.12–1.79)
45–54 years	1.00	1.45 (1.15–1.83)
55–64 years	1.00	1.10 (0.84–1.44)
≥ 65 years	1.00	1.11 (0.85–1.45)
Sex		
Female	1.00	1.25 (1.07–1.46)
Male	1.00	1.48 (1.21–1.80)
Race		
Non-hispanic white	1.00	1.49 (1.17–1.90)
Non-hispanic black	1.00	1.06 (0.91–1.23)
Mexican American and other hispanic	1.00	1.27 (1.10–1.46)
Other race, including multi-racial	1.00	0.99 (0.69–1.43)
Body mass index		
Normal weight (18.5–24.9 kg/m ²)	1.00	1.38 (1.05–1.80)
Overweight (25.0–29.9 kg/m ²)	1.00	1.58 (1.27–1.96)
Obese (≥ 30.0 kg/m ²)	1.00	1.24 (1.08–1.42)

* Adjusted for age, sex, race, and body mass index.

security, but not when comparing participants with very low food security to those with full and marginal food security (Table 3).

In a sensitivity analysis with full food security as the reference group, findings were consistent with previous analyses (Table 4). When compared to participants with full food secu-

urity, participants with marginal food security were 1.27 (95% CI: 1.12–1.44) times more likely to have prediabetes. Likewise, participants with low/very low food security were 1.39 (95% CI: 1.20–1.60) times more likely to have prediabetes. Stratified analyses yielded similar findings to those estimated with a combined reference group of full/marginal food security.

Table 3 – Secondary analyses exploring a dose-response in the association between food security and laboratory-confirmed prediabetes, ages ≥ 20 years in the National Health and Nutrition Examination Survey (NHANES), 2005–2014.

Characteristic	Prediabetes		
	Full/marginal food security	Low food security	Very low food security
Total	aOR (95% CI) 1.00	aOR (95% CI) 1.38 (1.17–1.63)	aOR (95% CI) 1.30 (1.07–1.57)
Age			
20–34 years	1.00	1.31 (1.03–1.67)	1.78 (1.28–2.47)
35–44 years	1.00	1.48 (1.14–1.92)	1.33 (0.96–1.83)
45–54 years	1.00	1.48 (1.07–2.05)	1.41 (1.03–1.93)
55–64 years	1.00	1.28 (0.93–1.76)	0.88 (0.61–1.27)
≥ 65 years	1.00	1.21 (0.90–1.63)	0.95 (0.61–1.47)
Sex			
Female	1.00	1.25 (1.03–1.52)	1.24 (0.98–1.56)
Male	1.00	1.54 (1.25–1.91)	1.39 (1.06–1.82)
Race			
Non-hispanic white	1.00	1.55 (1.12–2.15)	1.41 (1.01–1.98)
Non-hispanic black	1.00	1.07 (0.90–1.28)	1.05 (0.81–1.35)
Mexican American and other hispanic	1.00	1.31 (1.12–1.54)	1.18 (0.91–1.54)
Other race, including multi-racial	1.00	1.02 (0.65–1.61)	0.94 (0.53–1.67)
Body mass index			
Normal weight (18.5–24.9 kg/m ²)	1.00	1.39 (1.00–1.94)	1.36 (0.94–1.96)
Overweight (25.0–29.9 kg/m ²)	1.00	1.53 (1.16–2.01)	1.66 (1.22–2.27)
Obese (≥ 30.0 kg/m ²)	1.00	1.28 (1.09–1.51)	1.17 (0.95–1.45)

* Adjusted for age, sex, race, and body mass index.

Table 4 – Sensitivity analysis with full food security as the reference group for the association between food security and laboratory-confirmed prediabetes, ages ≥ 20 years in the National Health and Nutrition Examination Survey (NHANES), 2005–2014.

	Prediabetes		
	Full Food Security	Marginal Food Security	Low/Very Low Food Security
Characteristic	aOR (95% CI)	aOR (95% CI)	aOR (95% CI)
Total	Reference	1.27 (1.12–1.44)	1.39 (1.20–1.60)
Age			
20–34 years	Reference	1.14 (0.88–1.49)	1.54 (1.20–1.99)
35–44 years	Reference	1.77 (1.41–2.22)	1.55 (1.22–1.97)
45–54 years	Reference	1.47 (1.07–2.03)	1.52 (1.20–1.92)
55–64 years	Reference	1.15 (0.83–1.59)	1.11 (0.85–1.45)
≥ 65 years	Reference	0.86 (0.67–1.10)	1.10 (0.84–1.44)
Sex			
Female	Reference	1.27 (1.04–1.55)	1.29 (1.10–1.51)
Male	Reference	1.27 (1.09–1.48)	1.52 (1.25–1.86)
Race			
Non-Hispanic White	Reference	1.37 (1.14–1.63)	1.53 (1.20–1.95)
Non-Hispanic Black	Reference	1.10 (0.88–1.37)	1.08 (0.92–1.26)
Mexican American and other hispanic	Reference	1.10 (0.86–1.41)	1.30 (1.11–1.51)
Other race, including multi-racial	Reference	0.92 (0.60–1.42)	0.98 (0.68–1.43)
Body mass index			
Normal weight (18.5–24.9 kg/m ²)	Reference	1.65 (1.13–2.41)	1.45 (1.10–1.92)
Overweight (25.0–29.9 kg/m ²)	Reference	0.94 (0.76–1.16)	1.57 (1.26–1.95)
Obese (≥ 30.0 kg/m ²)	Reference	1.38 (1.14–1.65)	1.30 (1.12–1.51)

* Adjusted for age, sex, race, and body mass index.

4. Discussion

While some studies have examined the relationship between food insecurity and diabetes, relatively little has been published on prediabetes and food insecurity. This analysis of a nationally representative sample of the U.S. population found that food insecurity was significantly associated with prediabetes. Controlling for age, sex, race, and BMI, food insecurity was associated with 1.35 (95% CI: 1.17–1.55) times greater odds of prediabetes compared with food security in this study population. This finding may support that food insecurity is independently associated with prediabetes.

While data from the National Diabetes Statistics Report published in 2017 [23] indicate that prediabetes is more prevalent among females than males, we found that females who were food insecure had 25% greater odds of prediabetes while males who were food insecure had 48% greater odds of prediabetes when compared to those who were food secure. These findings are not supported by a recent cross-sectional analysis of 2011 and 2012 National Health Interview Survey (NHIS) data [24], which included 19,048 adults aged 18–59 years with household income $\leq 299\%$ federal poverty line. The authors found that food insecure females had 62% greater odds of having prediabetes compared with food secure females (95% CI: 1.22–2.16) while food insecure males did not have greater odds of having prediabetes compared with their food secure counterparts (aOR = 1.09; 95% CI: 0.78–1.53) [24]. Potential explanations for the differences in findings are the classification of the prediabetes outcome, which was self-reported in the NHIS study and laboratory-confirmed in the present study, and the time frame of data collection. While the NHIS study analyzed data from two years, our study included data from ten consecutive years.

The National Diabetes Statistics Report data also indicated that prediabetes in the general population is more prevalent among non-Hispanic Blacks (36.3%) and non-Hispanic Asians (35.7%) than non-Hispanic Whites (31.5%) and Hispanics (31.7%) [23]. This study found that food insecure non-Hispanic Whites had 49% greater odds of prediabetes and Mexican American and Other Hispanics had 27% greater odds of diabetes compared with their food secure counterparts. The likelihood of prediabetes among food insecure non-Hispanic Blacks and Other Races was not significantly greater than among those who were food secure.

In relation to age, the highest likelihood of prediabetes in the present study was among 20–34 year olds at 1.5 times greater odds, followed by 45–54 year olds (aOR = 1.45) and 35–44 year olds (aOR = 1.42). Although other research has found that overweight and obesity are associated with prediabetes [24], there was a greater likelihood of prediabetes in our study population for all weight categories including normal weight. Overall, these findings argue for a non-traditional presentation of prediabetes among the food insecure.

Secondary analyses were conducted to investigate whether there was a dose-response in moving from low food security to very low food security. Worsening food insecurity did not make a difference in the likelihood of prediabetes, except among the 20–34 year olds. In this age group, the low food secure had 31% greater odds of prediabetes and the very low food secure had 78% greater odds of prediabetes than those who were food secure. The fact that an overall dose-response was not observed argues for the positive association between food insecurity at any level and negative health outcomes.

Strengths of this study include the use of the validated USDA Food Security Scale to measure the food security exposure rather than extrapolating from poverty level, and the use of laboratory-confirmed prediabetes outcome rather than self-report. Additionally, both the primary and secondary analyses yielded consistent results, indicating that food insecurity at any level is associated with prediabetes. As well, the sensitivity analysis including underweight individuals did not change findings by BMI, further indicating the rigor of the estimates of association. Finally, this study exhibits strong external validity because the data are derived from a representative sample of the general U.S. population.

One limitation of this study is the cross-sectional nature of NHANES data which precludes causal interpretation of results. However, these findings are biologically plausible and are consistent with other studies investigating the association between food security and negative health outcomes [7,10,25]. Additionally, social desirability bias may lead to under-reporting of food insecurity and subsequently result in underestimation of the association between food security status and prediabetes. However, this study employed the USDA-validated food security scale, which is the most robust measure available to approximate food security status.

The results of this research have several implications to practice. First, health screenings for prediabetes should be conducted at food pantries in order to increase awareness of food insecure individuals, particularly males and younger age groups. It has previously been reported that adult men with food insecurity were more likely to have undiagnosed prediabetes than food secure men, suggesting that food insecure men may lack awareness of their diabetes risk [26]. Partnering with hospital systems is an effective way to provide additional services to compliment the food distribution. Participants should also be educated on the greater likelihood of developing prediabetes and the non-traditional presentation among those that are food insecure. Next, programming should be provided for those that are prediabetic. Healthy food boxes coordinated with cooking demonstrations and educational classes such as Center for Disease Control's Diabetes Prevention Program are effective methods to promote lifestyle change and decrease the development of diabetes. Programs should also focus on the younger age groups. Finally, the results of this study suggest potential policy changes within food pantries and food banks, such as promoting healthier food donations and increasing produce distribution.

Appendix A. Supplementary material

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.diabres.2018.11.017>.

REFERENCES

- [1] Centers for Disease Control and Prevention. Prediabetes; 2017. <https://www.cdc.gov/diabetes/basics/prediabetes.html> [accessed 18 June 2018].
- [2] Centers for Disease Control and Prevention. National diabetes statistics report; 2017. <https://www.cdc.gov/diabetes/pdfs/data/statistics/national-diabetes-statistics-report.pdf> [accessed 18 June 2018].
- [3] Koller KR, Metzger JS, Jolly SE, Umans JG, Hopkins SE, Kaufmann C, et al. Cardiometabolic correlates of low type 2 diabetes incidence in western Alaska Native people – the WATCH study. *Diabetes Res. Clin. Pract.* 2015;108:423–31. <https://doi.org/10.1016/j.diabres.2015.03.001>.
- [4] Murthy VH. Food insecurity: a public health issue. *Publ Health Rep* 2016. <https://doi.org/10.1177/0033354916664154>.
- [5] Rabbitt MP, Coleman-Jensen A, Gregory CA. Understanding the prevalence, severity, and distribution of food insecurity in the United States; 2017, Jun 01.
- [6] Castillo DC, Ramsey NL, Yu SS, Ricks M, Courville AB, Sumner AE. Inconsistent access to food and cardiometabolic disease: the effect of food insecurity. *Curr Cardiovasc Risk Rep* 2012.
- [7] Pan L, Sherry B, Njai R, Blanck HM. Food insecurity is associated with obesity among US adults in 12 states. *J Acad Nutr Diet* 2012. <https://doi.org/10.1016/j.jand.2012.06.011>.
- [8] Berkowitz SA, Baggett TP, Wexler DJ, Huskey KW, Wee CC. Food insecurity and metabolic control among U.S. adults with diabetes. *Diabetes Care* 2013. <https://doi.org/10.2337/dc13-0570>.
- [9] Seligman HK, Laraia BA, Kushel MB. Food insecurity is associated with chronic disease among low-income NHANES participants. *J. Nutr.* 2010. <https://doi.org/10.3945/jn.109.112573>.
- [10] Gundersen C, Ziliak JP. Food insecurity and health outcomes. *Health. Aff. (Millwood)* 2015. <https://doi.org/10.1377/hlthaff.2015.0645>.
- [11] Drewnowski A, Specter SE. Poverty and obesity: the role of energy density and energy costs. *Am. J. Clin. Nutr.* 2004. <https://doi.org/10.1093/ajcn/79.1.6>.
- [12] Kendall A, Olson CM, Frongillo Jr EA. Relationship of hunger and food insecurity to food availability and consumption. *J Am Diet Assoc* 1996.
- [13] Pereira MA, Kartashov AI, Ebbeling CB, Van Horn L, Slattery ML, Jacobs Jr DR, et al. Fast-food habits, weight gain, and insulin resistance (the CARDIA study): 15-year prospective analysis. *Lancet* 2005.
- [14] Hu FB, van Dam RM, Liu S. Diet and risk of Type II diabetes: the role of types of fat and carbohydrate. *Diabetologia* 2001. <https://doi.org/10.1007/s001250100547>.
- [15] Bove CF, Olson CM. Obesity in low-income rural women: qualitative insights about physical activity and eating patterns. *Women Health* 2006. https://doi.org/10.1300/J013v44n01_04.
- [16] Gowda C, Hadley C, Aiello AE. The association between food insecurity and inflammation in the US adult population. *Am J Public Health* 2012. <https://doi.org/10.2105/AJPH.2011.300551>.
- [17] Centers for Disease Control and Prevention. National Center for Health Statistics. National health and nutrition examination survey; 2017. <https://www.cdc.gov/nchs/nhanes/index.htm> [accessed 27 June 2018].
- [18] Schisterman EF, Cole SR, Platt RW. Overadjustment bias and unnecessary adjustment in epidemiologic studies. *Epidemiology* 2009. <https://doi.org/10.1097/EDE.0b013e3181a819a1>.
- [19] Vaccaro JA, Huffman FG. Sex and race/ethnic disparities in food security and chronic diseases in U.S. older adults. *Gerontol Geriatr Med* 2017. <https://doi.org/10.1177/2333721417718344>.
- [20] Centers for Disease Control and Prevention. Who is at risk? 2017. <https://www.cdc.gov/diabetes/basics/risk-factors.html> [accessed 31 May 2018].
- [21] Wilde PE, Peterman JN. Individual weight change is associated with household food security status. *J Nutr* 2006.

- [22] Centers for Disease Control and Prevention. NHANES Web tutorial frequently asked questions (FAQs); 2014. <https://www.cdc.gov/nchs/tutorials/nhanes/faqs.htm> [accessed 31 May 2018].
- [23] Murillo R, Reesor LM, Scott CW, Hernandez DC. Food insecurity and prediabetes in adults: race/ethnic and sex differences. *Am J Health Behav* 2017. <https://doi.org/10.5993/AJHB.41.4.7>.
- [24] Li C, Ford ES, Zhao G, Mokdad AH. Prevalence of prediabetes and its association with clustering of cardiometabolic risk factors and hyperinsulinemia among U.S. adolescents: national health and nutrition examination survey 2005–2006. *Diabetes Care* 2009. <https://doi.org/10.2337/dc08-1128>.
- [25] Darling KE, Fahrenkamp AJ, Wilson SM, D'Auria AL, Sato AF. Physical and mental health outcomes associated with prior food insecurity among young adults. *J Health Psychol* 2017. <https://doi.org/10.1177/1359105315609087>.
- [26] Ding M, Wilson NL, Garza KB, Zizza CA. Undiagnosed prediabetes among food insecure adults. *Am J Health Behav* 2014. <https://doi.org/10.5993/AJHB.38.2.8>.