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# Food insecurity is associated with prediabetes and dietary differences in U.S. adults aged 20–39

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ABSTRACT

Food insecurity has been linked with lifestyle and metabolic health differences in varying populations. We sought to assess how food insecurity may have been associated with prediabetes and dietary differences in a relatively young subset of U.S. adults. We examined data from the United States National Health and Nutrition Examination Survey (2003–2014) participants aged 20–39 with complete data regarding food insecurity and metabolic laboratory assessment. We also assessed macronutrient intake and Supplemental Nutrition Assistance Program (SNAP) usage. All logistic regression models controlled for age, sex, and household income. Among 3684 included participants, food insecurity had 19.12% (95% confidence interval [95%CI]: 16.16, 22.08) prevalence. Food-insecure participants had prediabetes/diabetes prevalence of 37.36% (95%CI: 30.47, 44.25) and higher odds of having prediabetes/diabetes (adjusted odds ratio [aOR] = 1.36, 95%CI: 1.00, 1.85). Food-insecure adults has significantly different macronutrient intake: higher carbohydrates ($p = 0.02$), less protein ($p = 0.01$), and less total fat ($p = 0.04$) consumption. Food-insecure adults who used SNAP (compared to food-insecure adults who did not use SNAP) had higher odds of having metabolic syndrome (ATP-III MetS) (aOR = 2.56, 95%CI: 1.27, 5.22). We found that food insecurity was relatively prevalent in this subset of younger U.S. adults. We showed that food-insecure participants had increased prevalence and odds of prediabetes. These associations were also correlated with dietary differences.

## 1. Introduction

Food insecurity and food assistance have been studied for several decades, with a current renewed interest given recent suggestions of policy reform (Nord, 2014; Thrush, 2018). Food insecurity has been observed to have adverse health associations that vary across population subgroups. In children, food insecurity is related to obesity and poorer cognitive/developmental outcomes (Cook et al., 2004; Johnson and Markowitz, 2018; Lee et al., 2018). In adults, food insecurity has been related to outcomes such as type 2 diabetes mellitus (T2DM) and depression (Gundersen and Ziliak, 2015; Heflin et al., 2005; Seligman et al., 2007).

Food assistance has complicated interactions with food insecurity and health outcomes. Multiple studies have demonstrated varying associations of food assistance, with use of the Supplemental Nutrition Assistance Program (SNAP) linked in different studies to 1 - improved diet and weight status (Nguyen et al., 2015), 2 - no association with BMI in children aged 9–17 (Nguyen et al., 2017), and 3 - an increase in cardiovascular disease mortality in adults older than 25 (Conrad et al., 2017).

Metabolic syndrome (MetS) is a cluster of metabolic abnormalities (obesity, dyslipidemia, hypertension, and hyperglycemia) associated with multiple adverse outcomes (DeBoer et al., 2015a, 2015b). Prediabetes is a state of abnormal blood sugar elevation that has a strong likelihood of progressing to T2DM left untreated (Lee et al., 2017; Nichols et al., 2007). Both of these conditions are related to obesity and strongly portend cardiometabolic risk. Intervention on these conditions is primarily dependent upon lifestyle modification. Thus, it is important to understand how factors such as food insecurity (which has associations with obesity) affect MetS and prediabetes risk; and how interventions such as SNAP modify those risks.

Our goal was to examine whether the associations of food insecurity with MetS and prediabetes could be observed in a large sample of U.S. adults aged 20–39. This age group represents a population in which

*Abbreviations:* T2 dm, Type 2 diabetes mellitus; SNAP, Supplemental Nutrition Assistance Program; MetS, Metabolic syndrome; MetS z-score, Metabolic syndrome severity score; CDC, Center for Disease Control and Prevention; NHANES, National Health and Nutrition Examination Survey; USDA, United States Department of Agriculture

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there has been a relative paucity of food insecurity research (Nord, 2014). Additionally, we investigated if significant lifestyle differences existed on the bases of food security status or SNAP utilization. Lastly, we sought to examine if and how SNAP utilization modified any observed associations.

## 2. Methods

We examined the Center for Disease Control and Prevention's (CDC) National Health And Nutrition Examination Survey (NHANES) data from participants aged 20–39 years (2003–2014). This study was approved by the National Center for Health Statistics ethics review board. Participants provided informed consent. NHANES is a cross-sectional, national, stratified, multistage probability survey conducted in 2-year waves with randomly selected non-institutionalized U.S. civilians. Race/ethnicity was self-reported as Hispanic (either white or black), non-Hispanic white, and non-Hispanic black (subsequently referred to as Hispanic, white, and black). The study design included intentional oversampling of racial/ethnic minorities and participants with household income below 130% of the federal poverty level in order to allow more precise comparisons by race/ethnicity and income. NHANES then derived sample weights by participant sub-group to account for the intentional oversampling as well as differences in response rate based on region and demographic in an effort to create a nationally representative sample (National_Center_for_Health_Statistics, 2016). Additional weights were derived based on fasting status for laboratory measures. All analyses took these study weights into account to provide results that are nationally-representative for the US population.

Food security was assessed with the Bickel et al. (2000) and Nord and Bickel (2002). This survey was only administered to participants with household income-to-poverty ratio < 4.0, using the Federal Poverty Level threshold released yearly by the US government (e.g., in 2014, $23,850 for a family of four). 10 items on the questionnaire were directed at adult and household experience with food insecurity. An additional 8 items were directed at child-specific experiences for households with children. A composite household food security scaled score and classification was created using the first ten items for participants with no children in the household, and with all 18 items for participants with children in the household. Food stamps utilization was self-reported.

Dietary intake was determined based on two 24-h food recall interviews administered by a trained dietary interviewer using a 4-step multi-pass approach. The 1st recall interview was administered on examination day at the mobile examination centers. The 2nd recall interview was conducted over telephone. Interview data were processed and coded to determine macronutrient intake based on the USDA National Nutrient Database for Standard Reference (USDA, Accessed 8/14/2015). Total macronutrient intake (in grams) was calculated as an average of the two interviews. Macronutrient consumption was reported as a percentage of total calorie consumption as accounted by specific macronutrient (Reedy and Krebs-Smith, 2010). The equation was as follows: % total energy from #macronutrient = (#multiplier * grams intake)/total calories; (#specific macronutrient and multipliers, carbohydrates & protein = 4, fats = 9).

Anthropometric, clinical, and laboratory data was collected with standardized protocols and equipment (Kuczmarski et al., 2000). Fasting blood samples were obtained from participants who attended morning sessions at the mobile examination centers after at least 9 h of fasting. Elevated blood pressure was defined as the average systolic or diastolic blood pressure exceeding 130 or 85 respectively, or being on anti-hypertensive medication. MetS was evaluated with the Adult Treatment Panel III (ATP-III) criteria (at least 3 of 5: elevated BMI, blood pressure, fasting triglycerides, fasting glucose, or reduced HDL) and with the metabolic syndrome severity score (MetS z-score – http://mets.health-outcomes-policy.ufl.edu/calculator) (Alberti et al., 2009; Grundy et al., 2005; Gurka et al., 2012). Prediabetes was defined as hemoglobin-A1C (A1C) between 5.7 and 6.4%. or fasting glucose ≥100–126. Diabetes was defined as A1C > 6.4%, fasting glucose ≥126, or diabetic medication use (Amer Diabet, 2014).

Participants aged 20–39 years were included for analysis. Only Hispanic, white, and black participants were included because the MetS z-score has only been derived for these groups. Participants were excluded on the basis of pregnancy on examination day, non-fasting status, incomplete MetS laboratory data, missing household income data, non-diabetes medication affecting manifestation of MetS and incomplete food security assessment. Pregnancy status and non-diabetes medications affecting MetS manifestation were used as exclusion criteria because of their potential to alter laboratory data and weight status. Only participants with household income-to-poverty ratio < 4.0 were included because the food security assessment was not administered outside that group. The major excluding factor was incomplete MetS laboratory data due to fasting labs being drawn on only half of all NHANES participants.

Statistical analyses were performed with SAS (version 9.4, Cary, NC). Survey procedures were used to account for complex survey design and incorporated sample weights. Differences in proportions within sub-groups (e.g., food secure v food insecure) were compared via Chi-square tests. Least squares means analyses were used to show differences in clinical measurements between different subgroups. Odds ratios were calculated using SURVEYLOGISTIC, comparing odds of a given characteristic (e.g. obesity) being present among those with v without food insecurity. All statistical analyses adjusted for age, sex, and household income-to-poverty ratio. Education level was not included as a co-variate given concern for excess collinearity with household income (correlation coefficient in regression of income and education = 0.635, standard error of the mean = 0.030, $p < 0.0001$).

## 3. Results

### 3.1. Demographics

There were 3684 NHANES participants aged 20–39 who met all sample group inclusion criteria (Supplementary Fig. 1). Table 1 reports demographic characteristics for the sample. Food insecurity was present in 19.12 (95%CI: 16.16, 22.08) of the sample. Chi-square analyses revealed differences in food-insecurity prevalence based within race/ethnicity and household income-to-poverty ratio, with the proportion of food-insecure participants was higher among Hispanic and black participants compared to white participants ($p < 0.0001$, Table 1). The proportion of food-insecure participants was also higher among participants with lower household income. Average age of all participants was 30.24 years (standard deviation $7.8 \times 10^7$, standard error of the mean 0.18). There was no difference in age based on food security status (difference estimate = 0.80 years, 95%CI: −1.21, 1.05).

Education data was available for 3612 of the 3684 included participants Supplementary Table 1). Education level was divided as 3 categories: no high school diploma (proportion = 13.91%, 95%CI: 11.61, 16.21), high school diploma (proportion = 18.24%, 95%CI: 15.41, 21.07), and additional education after high school (proportion = 67.85%, 95%CI: 61.41, 74.29). Chi-square analysis showed differences in food-insecurity prevalence based within education level). with a higher proportion of food insecurity among participants with less education ($p < 0.0001$, Supplementary Table 1).

Analysis of the excluded participants showed differences by sex and race/ethnicity but no differences on the basis of age, household income of food insecurity compared to the included sample (Supplementary Table 2). All participants classified as “other” race/ethnicity were in the excluded group due to the MetS z-score being not yet derived for these participants.

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