Food Insecurity is Associated with Metabolic Syndrome in a Gender-Specific Manner among NHANES Participants 1999-2014

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Abstract

Background: In 2011, it was estimated that 14.9 percent of households were food insecure at least some of the year. To date, there is limited data on the association between food insecurity and early indicators of poor cardiometabolic health, such as metabolic syndrome. Metabolic syndrome is associated with a twofold increased risk of developing cardiovascular disease and a fivefold increase risk in developing type 2 diabetes. A better understanding of the association between food insecurity and poor metabolic health can improve the effectiveness of public health interventions.
Methods: This study used data from 11,071 18-65yr old participants collected as part of National Health and Nutrition Examination Survey 1999-2014. The association between food insecurity and metabolic syndrome was estimated using relative risk regression. We adjusted for race/ethnicity, age, physical activity, smoking status, education and income. Food insecurity was analyzed as both a binary (secure/insecure) and ordinal (full/marginal/low/very low food security) variable. Age, gender, and race/ethnicity were evaluated for effect modification.
Results: The unadjusted prevalence of metabolic syndrome in food insecure females (39(36-43) per 100 persons) was higher than in food insecure males (27(23-32) per 100 persons). The unadjusted prevalence of metabolic syndrome increased with higher severity of food insecurity in females. Food insecurity was associated with metabolic syndrome in females [adjusted relative risk (ARR) 1.54(1.13-2.11)] but not in males [ARR 1.06(0.77-1.46)]. Low food security was associated with metabolic syndrome (when compared to full food security) in females [ARR 0.90(1.22-0.84)] but not males [ARR 1.19(0.79-1.79)].
Conclusions: Food insecurity is associated with a moderately increased risk of metabolic syndrome in females. Further research is required to understand the reasons for these gender differences. It is important for public health professionals to consider access to affordable high quality food when working to promote good metabolic and cardiovascular health.

Introduction

Starting with the early 1980's, there began to be recognition in the United States that many households faced limited or uncertain access to adequate food in ways that differed from malnutrition and chronic hunger, which were especially prevalent in developing countries[1]. The USDA defines food insecurity as "limited or uncertain availability of nutritionally adequate and safe foods or uncertain ability to acquire acceptable foods in socially acceptable ways" and hunger as "the uneasy or painful sensation caused by a lack of food, the recurrent and involuntary lack of access to food. Hunger may produce malnutrition over time. Hunger is a potential, although not necessary, consequence of food insecurity"[2]. In 1995, the 18 item U.S. Food Security Survey Module was added to the Current Population Survey (CPS) to measure the prevalence of food insecurity in the US[1]. In 2011, it was estimated that 14.9 percent of U.S. households were food insecure at least some of the year and that the typical food secure household spent 24 percent more on food than the typical food-insecure household of the same size and composition[3]. Households reporting food insecurity may be more likely to consume low-nutrient energy dense foods[4] and report a lower frequency of consumption of fruits and vegetables[5]. Previous research has found an association between food insecurity and hyperglycemia, hypertension, diabetes[6,7], peripheral arterial disease[8], poor cardiovascular health[9], increased BMI in young women[10], and poor health outcomes in disabled adults[11]. Berkowitz et al. also found an association between food insecurity and poor metabolic control in adults with diabetes[12].

Metabolic syndrome is the presence of multiple interrelated risk factors for cardiovascular disease (CVD) and diabetes. Metabolic syndrome is associated with a two-fold increased risk for developing CVD and a five-fold increase in type 2 diabetes mellitus.[13] According to the CDC, heart disease was the leading cause of death and diabetes was the seventh leading cause of death in 2014[14]. A better understanding of the association between food security and poor cardiovascular and metabolic health can improve the effectiveness of public health interventions. To date, no studies have explored the association between food security and early indicators of poor cardiometabolic health other than BMI, but evidence suggests BMI may be a poor indicator[15]. This study aimed to explore the association between food insecurity and poor metabolic health before clinical disease may be present. This study will add to the scientific knowledge of how resource scarcity can contribute to poor health.

Methods

Data

This study used publicly available de-identified data from the Centers for Disease Control collected as part of the National Health and Nutrition Examination Study (NHANES), a cross-sectional, annual survey representative of the non-institutionalized US population[16]. The survey is conducted annually using a complex survey design and data are bundled into two-year cycles. Data were combined from eight NHANES cycles (1999 - 2014). Only individuals who were selected for the morning examination are included as fasting glucose and triglyceride samples were only collected in those sessions. Individuals under 18 and over 65 were excluded as were pregnant women. Participants with missing exposure, outcome, or covariate data were also excluded from analysis.

Food insecurity was measured by the Adult Food Security Category. This information was captured within the Food Security Questionnaire. NHANES used the 12-month scale of the US Household Food Security Survey Module (FSSM), which consists of 18 items and has a three-stage design[16]. The screening design keeps respondent burden to a minimum as most households are asked only three questions (five in households with children). The USDA evaluated the reliability of the questionnaire using both traditional methods such as Spearman-Brown, Rulon's and Cronbach's alpha and novel methods to account for the high proportion of respondents that answer all questions in the negative. All measures gave values greater than .69.[17] Responses are scored into four categories. In 2006, the food security category names were changed but the criteria did not[16,18]. 'Full Food Security' was defined as no on all items, 'Marginal Food Security' as yes on one to two items, 'Low Food Security' as yes on three to five items and 'Very Low Food Security' as yes on six to ten items. (Only 10 items are used in the scoring of adult food security, the remaining eight are used for child food security.) Responses to individual questions were not provided for confidentiality reasons. Food insecurity was defined as those individuals whose reported food security was 'low food security' or 'very low food security' following guidance by the USDA[2].(Table 1)

Table 1: Food Security Categories and Status

Number of Yes Responses	Food Security Categoty	Food Security Status
0	Full Food Security	Food Secure
1-2	Marginal Food Security	" "
3-5	Low Food Security	Food Insecure
6-10	Very Low Food Security	" "

Metabolic syndrome was defined using the harmonization criteria proposed in the joint interim statement of the International Diabetes Federation Task Force on Epidemiology and Prevention; National Heart, Lung, and Blood Institute; American Heart Association; World Heart Federation; International Atherosclerosis Society; and International Association for the Study of Obesity[13]. Individuals who met three or more of the following criteria were deemed to have metabolic syndrome: 1) waist circumference: $\geq$ 102 cm for men and $\geq$ 88 cm for women, 2) blood pressure: average systolic $\geq$ 130 mm Hg or average diastolic $\geq$ 85 mm Hg or reported taking a prescribed drug to lower blood pressure, 3) triglycerides: $\geq$ 150 mg/dL or reported taking a prescribed drug to lower cholesterol, 4) HDL: $\geq$ 40 mg/dL men and $\geq$ 50 mg/dL women, 5)fasting glucose: $\geq$ 100mg/dL or reported taking a prescribed drug to lower blood sugar (Table 2).

Table 2: Individuals with 3 or more criteria were classified as having metabolic syndrome

	Criteria
Waist Circumference	$\geq$ 102 cm for men and $\geq$ 88 cm for women
Blood Pressure	Average systolic $\geq$ 130 mm Hg or average diastolic $\geq$ 85 mm Hg or reported taking a prescribed drug to lower blood pressure
Triglycerides	$\geq$ 150 mg/dL or reported taking a prescribed drug to lower cholesterol
HDL	$<$ 40 mg/dL men and $<$ 50 mg/dL women
Fasting Glucose	$\geq$ 100mg/dL or reported taking a prescribed drug to lower blood sugar

Covariates known to be associated with metabolic syndrome and/or food security were included. Included covariates were age, gender, race/ethnicity, education, income, physical activity and smoking status. Until 2011, NHANES categorized race/ethnicity as 'Mexican-American', 'Other Hispanic', 'Non-Hispanic White', 'Non-Hispanic Black' and 'Other (including multiracial)'. In 2011, NHANES started collecting data for Asians, however to preserve continuity, an alternative race/ethnicity variable was created to match the pre-2011 variables. This variable was used since cycles from before and after 2011 were combined. Annual family income was used for income. Income was collapsed into four categories "$<$ \$20,000", "\$20,000 - \$54,999", "\$55,000-\$74,999", and "$\geq$ \$75,000". Some participants answered "under \$20,000" or "over \$20,000" in lieu of the narrower income categories, but "over \$20,000" was felt to be too broad a range and these responses were excluded. Education was collapsed to five categories "Less than 9th Grade", "9-11th Grade", "High School Grad", "Some College/AA" and "College Graduate or above". For participants in NHANES cycles before 2007, moderate physical activity was a yes answer to the question "Over the past 30 days, did you do moderate activities for at least 10 minutes that cause only light sweating or a slight to moderate increase in breathing or heart rate? Some examples are brisk walking, bicycling for pleasure, golf, and dancing.", after 2007 the questionnaire was changed and moderate physical activity was a yes answer to either of the questions: "Does your work involve moderate-intensity activity that causes small increases in breathing or heart rate such as brisk walking or carrying light loads for at least 10 minutes continuously?" or "Do you do any moderate-intensity sports, fitness, or recreational activities that cause a small increase in breathing or heart rate such as brisk walking, bicycling, swimming, or golf for at least 10 minutes continuously?". No to moderate physical activity was defined as not answering yes to any of the previous three questions when at least one of them was answered (not all missing). Never smokers were those who reported smoking less than 100 cigarettes in life. Former smokers were those who reported smoking at least 100 cigarettes in life but who reported they do not smoke now. Current smokers were those who reported smoking at least 100 cigarettes in life and reported smoking now. "In order to look at differences in prevalence of metabolic syndrome and food insecurity by age and NHANES cycle, age was categorized for those analyses only. Age categories were 20-29, 30-39, 40-49, and 50-59.

Analysis

All analyses were performed using the *survey* package v(3.31.5)[19] in R version 3.3.2 (2016-10-31)[20]. The complex survey design was incorporated in all estimations. All participants with a non-zero fasting sub-sample MEC weight were included in the design object and those participants meeting inclusion/exclusion criteria were indicated by a subset variable. 16-year sub-sample weights were calculated according to the formula recommended by NHANES[21]. The masked variance pseudo-PSU was used to specify clusters and the masked variance pseudo-stratum was used to specify stratum in the design object. Relative risk regression (binomial generalized linear regression with a log link function) was used to obtain all relative risks[22–24]. Gender, age, and race/ethnicity were all evaluated for effect modification based on previous research findings[25–28] and expert opinion. The association between food insecurity and metabolic syndrome was evaluated both at the dichotomous food secure/food insecure level and for each categorical food security level (marginal, low, very low using full food security as the reference group). All covariates that were not found to be effect modifiers were adjusted for. Significance of interaction terms for effect modification was determined using a likelihood ratio test. All tests were performed at the 0.05 level of significance.

Results

There were 23,505 participants who were selected for the morning examination (fasting sub-sample MEC weight not equal to zero) of which 15,623 were 18-65 years old, 677 were excluded for pregnancy. 1,153 were missing information on metabolic syndrome, 274 were missing information on food security, and 2,448 were missing covariate information; these participants were also excluded from the analysis, giving a final n = 11,071. (Fig 1) Unweighted participant characteristics and missing food security and covariate information are given in Table 3, weighted participant characteristics and p-values in Table 4. Food secure individuals were significantly more likely to be non-Hispanic white, have higher levels of education and have higher incomes. They were also moderately more likely to be never smokers. Food secure individuals were only slightly more likely to be male and to report engaging in moderate physical activity.

The prevalence of metabolic syndrome generally increased with age but did not change over time. In contrast, the prevalence of food insecurity while generally decreasing with age, was higher in the most recent three NHANES cycles than in the previous five NHANES cycles. (Fig 2). There was not a significant interaction between age or race/ethnicity and food insecurity, but there was a significant interaction between gender and food insecurity ($p < 0.0001$). The unadjusted prevalence of metabolic syndrome in food insecure females was higher than in food insecure males (39(36-43) per 100 persons vs 27(23-32) per 100 persons). Unadjusted prevalence of metabolic syndrome increased with more severe food insecurity categories in females, but the same trend was not present in males (Table 5). Food insecurity was significantly associated with metabolic syndrome in females [adjusted risk ratio (ARR): 1.54 95% CI: 1.13 - 1.13] but was not significantly associated with metabolic syndrome in males [ARR: 1.06 95% CI: 0.77 - 0.77]. Low food security was also significantly associated with metabolic syndrome in females [ARR: 1.79 95% CI: 1.22 - 2.64] but very low food security was not [ARR: 1.42 95% CI: 0.84 - 2.39]. (Table 5)

Discussion

Food insecurity was significantly associated with metabolic syndrome in females suggesting that attempting to address these risk factors with diet and exercise without regard to resource scarcity may be ineffective. Females experiencing food insecurity may be more likely to consume high calorie nutrient poor foods that make metabolic syndrome more likely. Previous studies have also found gender differences in associations between food insecurity and health outcomes[26–28]. Jansen et al, in a study of preschoolers, found an association between becoming food insecure and increased BMI and between becoming food secure and increased diet quality in girls but not in boys[25]. The gender differences in response to low food security warrant further exploration. There may be reporting differences between men and women. Men may feel less comfortable reporting food insecurity.

A recent meta-analysis found that the odds for household food insecurity was 40% higher where woman were the respondent and that female-headed households were 75% more likely to be food insecure than male-headed households[29]. This suggests that there are gender differences in both reporting and in vulnerability. Differences in coping with food insecurity may also help explain gender differences. Martin et al. argued that the observed gender differences were in fact a reflection of mother vs. non-mother differences. They argued that mothers preferentially gave nutritious and healthy foods to their children, leading to the observed poor outcomes in women. They concluded that food insecurity mediates the relationship between income and weight, but that the management of food insecurity intersects with gender to explain differential risks for obesity between mothers and non-mothers.[30] Dhurandhar has suggested that social status effects the physiological responses to food insecurity, arguing that food scarcity leads to increased body fat stores in low social status individuals[31]. It is probable that some combination of all these factors are responsible for the observed gender differences. If there is differential reporting between males and females, this indicates that we may be underestimating the problem of food insecurity in males.

If females (especially mothers) are prioritizing the nutrition and health needs of others at the expense of their own, this could have significant health consequences for females in food insecure households that need to be addressed. The finding that female-headed households are more likely to be food insecure than male households leads us to conclude that continuing gender disparities in employment income may have serious health consequences. Interventions that address food insecurity in addition to diet and exercise must be developed. We must recognize that for many individuals healthy diet is not a choice.

The recent increase in the prevalence of food insecurity requires monitoring. It may be that it is a result of the 2009 recession, and recent USDA studies indicate the trend may be stabilizing or reversing[32]. However, even if this trend is a result of the economic downturn and the prevalence decreases as economic conditions improve, we must be vigilant in future economic downturns to protect our most vulnerable citizens.

Strengths and Limitations

By combining eight NHANES cycles, we were able to obtain a large sample size. The sixteen year nature of our study also ensured our findings were not based on a relationship at a single point in time. In addition, the NHANES study cohort was designed to be representative of the US population giving our study good generalizability and external validity.

The biggest limitation of this study is the cross-sectional design. The cross-sectional nature does not allow us to account for any latency period in the development of metabolic syndrome in food insecure individuals. The prevalence of metabolic syndrome is higher in older ages and is likely a result of years of poor diet. The prevalence of food insecurity, however, goes down with age as wages and other causes of poverty tend to decrease. Due to the cross-sectional nature of this study, we were unable to analyze the effects of many years of food insecurity previously in individuals who are not food insecure currently on metabolic syndrome. The relative risk of metabolic syndrome in individuals classified as “very low food security” compared to “full food security” is also lower than in those classified as “low food security”. This may be because individuals who have very low food security may be experiencing hunger or malnutrition. While these conditions would have negative health effects, they may be less likely to cause metabolic syndrome.

The Food Security Survey Module assesses food insecurity at the household level, which may not accurately reflect the food security status of the individual. In addition, the classification of metabolic syndrome relied on single measurements at a specific moment in time, which may have resulted in the misclassification of some individuals. The large sample size minimizes the effect that we would expect this to have on the results.

Conculsions

Food insecurity in females was associated with a 54% (95% CI: 13% - 111%) increased risk in metabolic syndrome compared to food secure females. Low food secure females had a 79% (95% CI: 22% - 164%) higher risk for metabolic syndrome when compared to full food secure females. Our findings support other research that suggests that individuals respond to food insecurity in gender specific ways. Whether this is caused by physiological, environmental, or sociological factors or any combination of the three requires further research. Metabolic syndrome is associated with a twofold increased risk for cardiovascular disease and a fivefold increased risk for diabetes, the number one and number seven causes of death in the US. By addressing food security in individuals before they develop chronic disease, prevention efforts may be more effective.

Reproducible Research

Everything needed to reproduce this analysis in its entirety, including all code and related documentation, may be found at [http://github.com/ledbettc/Capstone-Project].

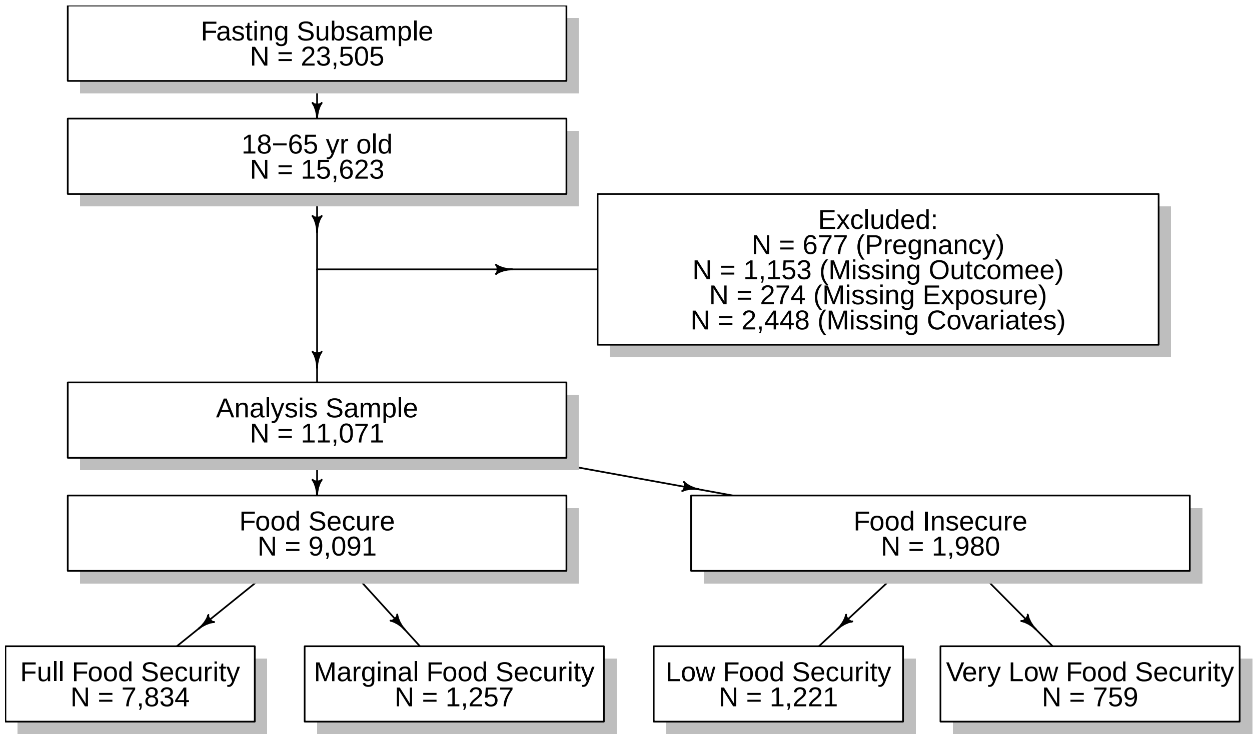

Figure 1: Cohort Flow Chart

Table 3: Characteristics of Study Participants by Food Security Category

	Full Food Security (n= 9,600)	Marginal Food Security (n= 1,530)	Low Food Security (n= 1,502)	Very Low Food Security (n= 887)	Missing (n= 274)
	N(%)	N(%)	N(%)	N(%)	N(%)
Gender					
Female	4661(49)	806(53)	747(50)	460(52)	134(49)
Race					
Non-Hispanic White	4569(48)	409(27)	387(26)	352(40)	86(31)
Mexican American	1631(17)	458(30)	508(34)	179(20)	81(30)
Other Hispanic	685(7)	156(10)	166(11)	102(11)	17(6)
Non-Hispanic Black	1856(19)	421(28)	361(24)	215(24)	71(26)
Other (including multiracial)	337(4)	32(2)	42(3)	18(2)	12(4)
Missing	522(5)	54(4)	38(3)	21(2)	7(3)
Education					
Less than 9th Grade	618(6)	190(12)	304(20)	133(15)	27(10)
9-11th Grade	1315(14)	343(22)	391(26)	226(25)	51(19)
High School Grad	2260(24)	419(27)	354(24)	240(27)	86(31)
Some College/AA	2906(30)	441(29)	352(23)	252(28)	73(27)
College Graduate or above	2497(26)	132(9)	100(7)	35(4)	36(13)
Missing	4(0)	5(0)	1(0)	1(0)	1(0)
Income					
$<$ **\$20,000**	1645(17)	594(39)	687(46)	493(56)	13(5)
\$20,000 - \$54,999	3315(35)	670(44)	596(40)	331(37)	92(34)
\$55,000-\$74,999	1227(13)	112(7)	65(4)	22(2)	29(11)
$\geq$ **\$75,000**	2861(30)	80(5)	44(3)	9(1)	26(9)
Missing	552(6)	74(5)	110(7)	32(4)	114(42)
Smoking Status					
Never	5047(53)	729(48)	678(45)	341(38)	138(50)
Former	1935(20)	240(16)	229(15)	117(13)	50(18)
Current	1838(19)	407(27)	440(29)	351(40)	50(18)
Missing	780(8)	154(10)	155(10)	78(9)	36(13)
Moderate Phys Act					
Yes	5657(59)	828(54)	775(52)	490(55)	144(53)
No	3942(41)	701(46)	726(48)	397(45)	129(47)
Missing	1(0)	1(0)	1(0)	0(0)	1(0)
	Mean(SD)	Mean(SD)	Mean(SD)	Mean(SD)	Mean(SD)
Age	41(14)	38(14)	39(14)	39(14)	39(15)

Table 4: Weighted Characteristics of Study Participants by Food Security Category

	Food Secure (n= 135,319,985)	Food Insecure (n= 19,836,878)	Fully Food Secure (n= 122,427,895)	Marginal Food Security (n= 12,892,090)	Low Food Security (n= 11,778,849)	Very Low Food Security (n= 8,058,029)	p-value
	N(%)	N(%)	N(%)	N(%)	N(%)	N(%)	
Gender							0.17
Female	66,695,440(49)	9,968,327(50)	59,909,429(49)	6,786,011(53)	5,889,069(50)	4,079,258(51)	
Moderate Phys Act							<0.01
No	50,559,587(37)	8,805,427(44)	44,995,299(37)	5,564,288(43)	5,363,157(46)	3,442,270(43)	
Race							<0.01
Non-Hispanic White	98,437,478(73)	10,480,189(53)	92,393,838(75)	6,043,639(47)	5,718,990(49)	4,761,199(59)	
Mexican American	10,340,803(8)	3,247,641(16)	7,875,168(6)	2,465,635(19)	2,386,064(20)	861,578(11)	
Other Hispanic	6,575,147(5)	1,756,020(9)	5,310,281(4)	1,264,866(10)	939,415(8)	816,604(10)	
Non-Hispanic Black	14,110,826(10)	3,655,731(18)	11,419,702(9)	2,691,124(21)	2,219,931(19)	1,435,800(18)	
Other (including multiracial)	5,855,731(4)	697,296(4)	5,428,906(4)	426,825(3)	514,449(4)	182,848(2)	
Education							<0.01
Less than 9th Grade	5,212,109(4)	2,448,762(12)	3,989,142(3)	1,222,966(9)	1,587,782(13)	860,979(11)	
9-11th Grade	14,120,024(10)	4,750,264(24)	11,644,487(10)	2,475,537(19)	2,919,312(25)	1,830,952(23)	
High School Grad	31,023,507(23)	5,008,015(25)	27,286,262(22)	3,737,245(29)	2,727,771(23)	2,280,243(28)	
Some College/AA	43,197,178(32)	6,269,125(32)	39,072,196(32)	4,124,982(32)	3,575,655(30)	2,693,470(33)	
College Graduate or above	41,767,167(31)	1,360,713(7)	40,435,808(33)	1,331,359(10)	968,328(8)	392,384(5)	
Income							<0.01
$< \$20,000$	19,759,001(15)	9,644,081(49)	15,025,307(12)	4,733,693(37)	5,295,747(45)	4,348,334(54)	
$20,000 - $54,999	46,860,369(35)	8,477,535(43)	40,773,026(33)	6,087,344(47)	5,088,881(43)	3,388,654(42)	
$55,000-$74,999	20,364,453(15)	956,909(5)	19,113,815(16)	1,250,637(10)	781,001(7)	175,908(2)	
$\geq \$75,000$	48,336,162(36)	758,352(4)	47,515,747(39)	820,415(6)	613,220(5)	145,132(2)	
Smoking Status							<0.01
Never	74,509,958(55)	8,474,294(43)	68,203,357(56)	6,306,601(49)	5,575,873(47)	2,898,422(36)	
Former	30,456,064(23)	3,134,453(16)	28,039,675(23)	2,416,388(19)	1,884,735(16)	1,249,718(16)	
Current	30,353,963(22)	8,228,130(41)	26,184,863(21)	4,169,100(32)	4,318,241(37)	3,909,889(49)	
	Mean(SD)	Mean(SD)	Mean(SD)	Mean(SD)	Mean(SD)	Mean(SD)	
Age	42(0.2)	39(0.4)	42(0.2)	38(0.5)	39(0.5)	39(0.7)	<0.01

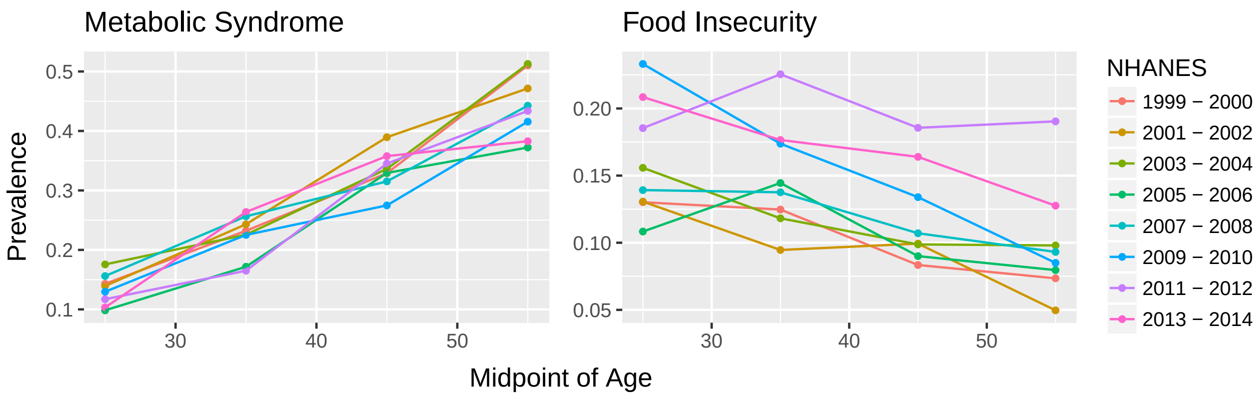

Figure 2: Prevalence of Metabolic Syndrome and Food Insecurity by Age and NHANES Cycle

Table 5: Unadjusted Prevalence and Relative Risk of Metabolic Syndrome by Food Insecurity Status/Category

	Male	Female
Unadjusted Prevalence per 100 persons		
Food Secure	31(30-33)	29(27-31)
Food Insecure	27(23-32)	39(36-43)
Full food security	32(30-34)	28(26-30)
Marginal food security	30(25-35)	33(29-39)
Low Food security	27(22-33)	38(34-43)
Very low Food security	27(22-33)	40(34-47)
Crude Relative Risk		
Food Insecure (vs. Secure)	0.86(0.74-1.00)	1.25(0.87-1.78)
Marginal Food Security (vs. Full)	0.94(0.80-1.11)	1.19(1.02-1.38)
Low Food Security (vs. Full)	0.85(0.70-1.04)	1.36(1.19-1.56)
Very Low Food security (vs. Full)	0.86(0.69-1.08)	1.43(1.20-1.71)
Adjusted Relative Risk		
Food Insecure (vs. Secure)	1.06(0.77-1.46)	1.54(1.13-2.11)
Marginal Food Security (vs. Full)	1.20(0.74-1.94)	1.44(0.90-2.30)
Low Food Security (vs. Full)	1.19(0.79-1.79)	1.79(1.22-2.64)
Very Low Food security (vs. Full)	0.99(0.58-1.70)	1.42(0.84-2.39)

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