Food Insecurity and Undiagnosed Chronic Conditions among Adults

by

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Abstract

The purpose of this thesis is to examine the relationship between food insecurity and undiagnosed chronic conditions, including prediabetes, hypertension and hyperlipidemia, among adults (20-64y). Food security status was assessed by the ten items for adults from Food Security Survey Module. Undiagnosed chronic conditions were determined by comparing self-reported information with clinical examination evidence. The clinical definition for prediabetes was fasting plasma glucose = 100-125 mg/dl or A1C =5.7-6.4%, for hypertension was blood pressure ≥ 140/90 mm Hg, and hyperlipidemia was defined by several criteria, including triglyceride, LDL, HDL and total cholesterol. Food insecure adults were more likely to have undiagnosed prediabetes (odds ratio 1.49, 95% CI 1.17-1.88). The relationship between food insecurity and undiagnosed hypertension and hyperlipidemia no longer existed after adjusting for confounding variables. These results indicate that food insecure adults may not know their risk status for diabetes. Screening for diabetes in food insecure populations appears to be warranted.

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List of Abbreviations

AHA	American Heart Association
AHR	Adjusted Hazard Ratio
ARR	Adjusted Risk Ratio
AOR	Adjusted Odds Ratio
CAD	Coronary Artery Disease
CDC	Centers for Disease Control
CKD	Chronic Kidney Disease
CPS	Current Population Survey
CRR	Crude Risk Ratio
CNSTAT	Committee on National Statistics
FASEB	Federation of American Societies for Experimental Biology
FPG	Fasting plasma glucose
FSS	Food Security Supplement
FSSM	Food Security Survey Module
IADLs	Instrumental Activities of Daily Living
LSRO	Life Sciences Research Office
NCHS	National Center for Health Statistics
NHANES	National Health and Nutritional Examination Survey
NPHS	National Population Health Survey

MEC	Mobile Examination Centers
OR	Odds Ratio
PIR	Poverty Income Ratio
SE	Standard Error
SIPP	Survey of Income and Program Participations
USDA	United States Department of Agriculture
y	Year

Chapter 1 General Introduction

An estimated 14.5 percent (17.2 million) households in US were considered food insecurity throughout the entire year of 2010, involving 32.6 million adults (1). Food insecurity is defined as "the availability of nutritionally adequate and safe foods or the ability to acquire acceptable foods in socially acceptable ways is limited or uncertain" (2). A competing priorities theoretical model proposes that families with limited resources, such as low family income, have to make choices among subsistence needs and health care needs (2-4). Families with limited resources may be forced to pay for basic needs, such as food, health insurance, or other competing needs, rather than health care services (5).

Food insecure individuals may be vulnerable to poor health outcomes. Food insecurity has been linked to diabetes (6-11), obesity, depression, impaired physical performance and chronic disease (12-15), as well as self-reported poorer health (11). Results regarding the relationship between food insecurity and hypertension have not been consistent: some have linked food insecurity to hypertension (11, 14), whereas others observed no associations (7, 10, 16). Results regarding the link between food insecurity and hyperlipidemia are also not consistent, two studies found food insecure women were more likely to have abnormal levels of LDL and TRG (12), TC and HDL(17), whereas others reported no relationship (7, 16, 18).

Several factors, including age, race, education, language and insurance have been related to undiagnosed chronic conditions (19-25). Health insurance has been highlighted; people with no insurance and no routine health care were reported more likely to have undiagnosed diabetes

(19), and individuals with undiagnosed hypertension and undiagnosed hyperlipidemia were found to lack health insurance(22, 25). Although food insecurity has been linked to several chronic conditions, no studies to our knowledge have examined the relationship between food insecurity and undiagnosed chronic conditions among a nationally representative sample.

The purpose of this thesis is to examine the relationship between food insecurity and undiagnosed chronic conditions, specifically prediabetes, hypertension and hyperlipidemia, among non-elderly adults (20-64y) in the United States. Efforts to control and reduce the prevalence of chronic disease may be more effective when they are initiated early during the progression of these conditions. For this reason prediabetes, hypertension and hyperlipidemia are highlighted in this study. The hypotheses of this study are that food insecure adults are more likely to have undiagnosed prediabetes, hypertension and hyperlipidemia.

Chapter 2: Review of Literature

2.1 Food Insecurity

2.1.1 Definitions of Food Security and Insecurity

In the U.S., definitions of food security and insecurity have been developed by an expert panel from the Life Sciences Research Office (LSRO) of the Federation of American Societies for Experimental Biology (FASEB) in 1989. According to the LSRO, food security was defined as, "Access by all people at all times to enough food for an active, healthy life and includes at a minimum: the ready availability of nutritionally adequate and safe foods, and the assured ability to acquire acceptable foods in socially acceptable ways."(2) The same group defined food insecurity as, "the availability of nutritionally adequate and safe foods or the ability to acquire acceptable foods in socially acceptable ways is limited or uncertain". The view of the National Research Council is that food insecurity results from social and economic problems that result in a lack of food. These might include a lack of physical access to food and the need to use emergency food supplies, scavenge or steal food, or other coping strategies (26). Voluntary fasting, dieting, or skipping meals do not fall under the definition of food insecurity.

2.1.2 Measurement of Food Insecurity

In the U.S., the primary purpose of measuring food security is to monitor the extent and severity of food insecurity among households (1). Such measures provide timely surveillance of food security status and permit the causes of food insecurity and the effects of food insecurity to be determined. This type of research should be used to develop food-related policy (1, 27).

Since 1995, the U.S. Department of Agriculture (USDA) has included a food security questionnaire as a supplement to the U. S. Census Bureau's Current Population Survey (CPS) to measure the food security status of U.S. households. Known as the Food Security Supplement (FSS), the results of this questionnaire have been used to estimate food insecurity (27, 28). The FSS included a set of 70 questions divided into five major sections (29): 1) food expenditures; 2) minimum food spending needed; 3) food assistance program participation; 4) food sufficiency and food security (18 food security and hunger questions that are used to calculate the household food security scale); and 5) ways of coping with not having enough food (27). The Food and Nutrition Service of the USDA uses a stable, robust, and reliable 18-item Food Security Survey Module (FSSM) at the household level, which is a core module chosen from the 70 questions in the FSS (27, 30). The 18-item FSSM has not changed since the original survey was fielded in April 1995 and was chosen to meet several statistical assumptions (31). These assumptions include:

1) a scale in a single dimension,
2) multiple items that express severity,
3) severity captured across items instead of within items, and
4) Guttman property, which is the affirmation of a more severe item should also mean that all less severe items were affirmed

The 18 items of the FSSM include a set of ten questions regarding households without children, to assess food security status among adults, and a set of eight questions to assess food insecurity among children (1). The severity of food insecurity ranges from worrying about food expenditures to assessing the frequency of skipping or cutting meals or losing weight because of a lack of food over 12 months (30). The FSSM questions are given in Appendix 1 (1).

Although the FSSM exhibits good statistical "fit" that has remained unchanged over the years, the cut-off points of the scale and household food security categories that describe the severity of food insecurity were revised by the USDA (31). In 1995, to simplify the food security scale into a small set of categories for both policy and research purposes, the USDA began to use four food security categories: food secure, food insecure without hunger, food insecure with moderate hunger, and food insecure with severe hunger (28). In 1999, the term "marginal food security" was added to yield the terms shown in Table 1: fully food secure, marginally food secure, food insecure without hunger, and food insecure with hunger (30). However, use of the word "hunger" was debated by the 2006 Committee on National Statistics (CNSTAT) panel, which finally recommended food insecurity be described using labels without the word "hunger" (27). The committee noted that food insecurity was a household-level economic and social condition, whereas hunger was an individual-level physiological condition that may result from food insecurity (27). In response to the recommendation by the CNSTAT panel (32),the USDA introduced new terms to describe the severity of food insecurity to include full food security, marginal food security, low food security, and very low food security (33). Because the methods to assess household food security are unchanged, the 2005 categories can be compared with those used between 1999-2005 (Table 1) (32).

Table 1. The USDA U.S. Household Food Security Categories regarding Adults.

1999-2005		2006-2010	
Food security category	Number of affirmative responses	Food security category	Number of affirmative responses
Fully food secure	0 item	Fully food secure	0 item
Marginal food security	1-2 items	Marginal food security	1-2 items
Food insecure without hunger	3-5 items	Low food security	3-5 items
Food insecure with hunger	6-10 items	Very low food security	6-10 items

Sources: Carlson 1999; USDA 2000; USDA 2011

Several surveys, such as the CPS, the Survey of Income and Program Participation (SIPP), and the National Health and Nutritional Examination Survey (NHANES) incorporate the FSSM (27). The Current Population Survey-Food Security Supplement (CPS-FSS) is a reliable survey estimating the prevalence of food security insecurity in subpopulations and has widespread acceptance as an authoritative source of statistical information; however, the CPS does not collect data on health characteristics making it difficult to link food security status and health outcomes (29). The SIPP, conducted by the U. S. Census Bureau, interviews all household members (≥ 15 y) and collects detailed social, economic, and some self-reported health information without clinical or laboratory health examination (27).

Starting in the 1960's, the NHANES, which collects health and nutrition data, has been conducted by the National Center for Health Statistics (NCHS) (34). The NHANES has become an annual survey since 1999 (35). While it has a smaller sample size than CPS, it is an important source of data to measure the relationship between food insecurity and health indicators(27)

2.1.3 Prevalence of Food Insecurity

According to data collected by CPS-FSS, about 11.8 percent (12.2 million) households experienced food insecurity including 22 million civilian noninstitutionalized adults in the U.S. in 1998 (36). An estimated 14.5 percent (17.2 million) of U. S. households (32.6 million adults) were considered to be food insecure in 2010 (1). In food insecure households, individuals reported that it was difficult at some time during the year to provide enough food for all members due to a lack of money and other resources (37). Most food insecure households avoided substantial reductions or disruptions in food intake by using a variety of coping strategies, such as reducing the variety of the diet or participating in Federal food assistance programs (30, 38). Households with very low food security experienced disrupted eating patterns and reduced food intake, at least some time during that year (33). In 1999, about 10 percent of households were food insecure(36). This percentage was about 12 percent in 2004, 11 percent in 2007, and about 14.5 percent in 2010 (1).

The CPS found variation in the prevalence of food insecurity in different subpopulations and among states (38). Food insecurity was more likely to exist in those households with incomes below the official poverty line, and less likely in those households with incomes above 185 percent of the poverty line (37, 38). Rates of food insecurity were higher than the national average for households with children, with a single parent, or those that were black or Hispanic (1, 37). Households located in principal cities of metropolitan areas had higher rates of food insecurity than the national average, and the prevalence of food insecurity was higher in the South and West than in the Midwest and Northeast (1).

Due to the variation in prevalence of food insecurity in different subpopulations reported by national surveys, researchers in this field have conducted studies to identify factors that contribute to the prevalence of food insecurity in the U.S. In previous studies, numerous causes have been identified, including low-income status, non-citizenship, unemployment, low education levels, minority race, poor physical status, limited accessibility to healthy food outlets, single-female headed households, households with three or more children, rented housing, central metro area and deprivation of socio-economic resources(1, 38-42). These factors often provoke a lack of money and other resources that may lead to food insecurity through changes in dietary intake or food behaviors.

2.2 Food Insecurity and Chronic Conditions

2.2.1 Health Consequences of Food Insecurity

Campbell noted consequences of food insecurity, including hunger, malnutrition, and poor physical health and overall quality of life either directly or indirectly through nutritional status (43). Subsequent to Campbell's work, researchers have reported on the health consequences of food insecurity. The following discussion will review the relationship between food insecurity and various health outcomes, including nutritional status, physical and mental health (11-13, 41, 44-49).

Food insecure persons have reported consuming less expensive foods, which typically have low nutrient density (50, 51). The diets of food insecure individuals have diets that are high in refined grains, added sugars and saturated /trans fats and have low nutrient density. Food insecurity has been linked to disrupted eating patterns, particularly skipping meals (52). However skipping meals did not translate into lower energy intakes. Women who were food insecure without hunger were reported to have more energy contributed from meals that were eaten and snacking than food secure women. Compared with food insecure persons, food insecure persons consumed lower levels of fruits, vegetables, dairy products (17, 47, 53). Rose found that individuals from food-insufficient households consumed less of most vitamins and minerals than did member of other households, which could increase the risk of nutrient deficiencies (41). Compared with their food-sufficient counterparts, adults from food-insufficient families had lower serum concentrations of vitamin A, vitamin E, and three carotenoids (α-carotene, β-cryptoxanthin and lutein/zeaxanthin) (17).

Food insecurity has been linked to obesity, depression, impaired physical performance, poor self-reported health status, food allergies (12-15). Food insecure persons were reported to have multiple chronic conditions, including heart disease, diabetes, high blood pressure (11, 47, 54). Recent findings of the relationships between food insecurity and obesity, diabetes, hypertension and hyperlipidemia are presented in Table 2 and are briefly reviewed in the following discussion.

2.2.2 Food Insecurity and Obesity

The association of food insecurity and obesity has been underscored by Dietz's hypothesis that physiological adaptation caused by food insufficiency could result in increased body fat (55). In recent years, studies have been conducted examining the association between food insecurity and obesity. Overall, food insecure adults were more likely to be obese than food secure counterparts (56). Primarily, intermediate levels of food insecurity have the positive relationship between food insecurity and obesity (57, 58). Among women, food insecurity and obesity are confirmed to be strongly and positively related (56). Food insecurity was significantly associated with obese mothers (59-61). Among men, some studies have found associations between food insecurity and obesity (57, 58), whereas others have found contradictory results (11). Tayie and Zizza reported that percentage of body fat, BMI and height were lower as food insecurity of male adults intensified(13). The mechanisms responsible for the association between food insecurity and obesity have not been clearly established.

2.2.3 Food Insecurity and Diabetes

Of the studies examining the relationship between food insecurity and type 1 and/or 2 diabetes, six studies found a relationship whereas two found no relationship (6-11, 14). The presence of type 2 diabetes mellitus has been measured in several different manners: self-reported, concentration of casual blood glucose, HbA1c, and fasting blood glucose. Food insecure respondents were more likely to have both self-reported or clinical evidence (fasting blood glucose≥126 mg/dl) diabetes than food secure respondents (9, 10). In a rural Ohio study, adults who have self-reported diabetes were significantly more likely to live in food insecure households (37.9%) than in food secure households (25.8%) ($\chi^2 = 19.3$, $P < .001$) (7). They also found that adults with an HbA1c level >7% (33.9%) were more likely to come from food insecure households than adults with HbA1c ≤7% (22.5%) ($P = .053$). Seligman et al. stated that food insecurity was associated with clinical evidence of diabetes (Adjusted Risk Ratio (ARR) 2.42; 95% CI, 1.44– 4.08), but not with self-reported diabetes (ARR 1.19; 95% CI, 0.89–1.58) (14). The risk of clinical diabetes among those who did not self-report a diagnosis of diabetes also appeared higher among adults living in food-insecure households than in food-secure households (Crude Risk Ratio (CRR) 2.73; 95% CI, 1.34–5.58) (14). One possible reason for this observation might be some of the individuals suffering diabetes were undiagnosed and the undiagnosed condition might relate to food insecurity. Hunger participants were also more likely to report chronic illness than their counterparts, including self-reported diabetes ($P < .001$) (6). In Canada, a National Population Health Survey (NPHS) study found individuals in food-insecure households were more likely to report multiple chronic conditions than those in food secure households, including self-reported diabetes (Adjusted Odds Ratio (AOR) 1.8; 95% CI, 1.2–2.6) (11). Another study from Canada reported that the mean HbA1c concentration was higher in people from food-insecure households compared with those from food-secure households (8). In contrast to all of these findings, Weigel et al. (16) and Parker et al. (18), observed no association between food insecurity and diabetes.

2.2.4 Food Insecurity and Hypertension

Three studies have reported an association between food insecurity and hypertension among adults (11, 14, 18); while three found no association (7, 10, 16). Hypertension was measured as self-reported hypertension or by sphygmomanometer test of systolic and /or diastolic blood pressure. Seligman et al. analyzed NHANES 1999-2004 and found food insecurity was related to both self-reported hypertension (ARR 1.20; 95% CI, 1.04–1.38) and clinical-evidence hypertension (ARR 1.21; 95% CI, 1.04–1.41) (14). Vozoris et al. (11) observed individuals in food insecure households were more likely to report high blood pressure than those in food secure households (AOR 1.6; 95% CI, 1.2–2.1). Systolic blood pressure differed by food security status ($P<.05$) (18), however, diastolic blood pressure was not found to have difference by food security status ($P> .05$) (7). Other studies also drew a conclusion that there was no significant association between food secure and food insecure individuals having hypertension (10, 16).

2.2.5 Food Insecurity and Hyperlipidemia

There were three studies observed associations between food insecurity and hyperlipidemia (12, 14, 17), whereas three found no association (7, 16, 18). Hyperlipidemia were determined by self-report or by testing concentration of blood lipid, such as HDL, LDL, TG and TC. Tayie and Zizza (12) demonstrated that the associations between food insecurity and hyperlipidemia were not consistent: among men, food insecurity was not related to hyperlipidemia; compared with food secure women, marginally food secure women were more likely to have abnormal levels of LDL (AOR, 1.85; $P=0.045$) and TRG/HDL ratio (AOR, 1.91; $P=0.046$); women who were food insecure without hunger were more likely to have abnormal levels of TRG (AOR, 1.90; P=0.041). Another NHANES study found that food insecure younger adults (20-59 y) had lower serum concentrations of TC (p=0.05), while food insecure older adults had lower serum concentrations of HDL (p=0.03), compared with their age groups counterparts (17). Food insecurity was also observed to be associated with self-reported hyperlipidemia (ARR 1.30; 95% CI, 1.09–1.55), but not with clinical-evidence hyperlipidemia (P = 0.4) (14). Three studies observed no association between food insecurity and hyperlipidemia (7, 16, 18).

Table 2. Studies on relationship between food insecurity and chronic conditions.

Author & Date	**Population**	**Subjects**	**Food Insecurity Measurement**	**Chronic Conditions Measurement**	**Main Findings**
			Food Insecurity and Diabetes		
Holben and Pheley 2006	Rural Ohio Cross-sectional	N=2580 Adults (average 44.7y)	Household Food insecurity: 18-item USDA FSSM	Self-reported diabetes; clinical measurement: blood glucose, and HbA1c	HbA1c were significantly greater among adults from food-insecure households. People who reported having diabetes were significantly more likely to live in food-insecure households (37.9%) than in food-secure households (25.8%) ($\chi2 = 19.3$, $P < .001$).
Marjerrison et al. 2010	Nova Scotia, Canada Cross-sectional	N=183 Children (≤18y)	Household Food insecurity: 18-item USDA FSSM	Clinical measurement: HbA1c	The mean HbA1c concentration was higher in the children from food-insecure households compared with those from food-secure households (9.5%, 2.13% vs 8.96%, 1.50%; $P = .039$). No association between food insecure children and DM.
Parker and Widome 2010	NHANES 1999-2006 Cross-sectional	N=6138 adults N=3113 adolescents	Household food insecurity: 18-item USDA FSSM	Clinical measurement: Glucose > 110 mg/dL; self-reported diabetes	No association
Seligman et al. 2007	NHANES 1999-2002 Cross-sectional	N=4,423 Adults (>20y)	Household Food insecurity: 10-item adults USDA FSSM	Clinical measurement: diabetes; self-report diabetes	Diabetes prevalence in the food secure, mildly food insecure, and severely food insecure categories was 11.7%, 10.0%, and 16.1%. Severely food insecure adults were more likely to have

					diabetes (AOR 2.1, 95% CI 1.1-4.0, p =0.02)
Seligman et al. 2010	NHANES 1999-2004 Cross-sectional	N=5094 Low-income adults (18-65y)	Household Food insecurity: 10-item adults USDA FSSM	Clinical measurement: (fasting glucose≥126 mg/dl); self-reported use of insulin or oral hypoglycemic medication); Self-reported diabetes	Food insecurity was associated with laboratory or examination evidence of diabetes (ARR 1.48; 95% CI, 0.94–2.32), but not self-reported diabetes (ARR 1.19; 95% CI, 0.89–1.58). The association with laboratory evidence of diabetes did not reach significance in the fully adjusted model unless they used a stricter definition of food insecurity (ARR 2.42; 95% CI, 1.44–4.08).
Terrell 2009	NHANES 1999-2004 Cross-sectional	N=15,199 Adults (average 45y)	Household Food insecurity: 18-item USDA FSSM	Self-reported diabetes	Food insecure respondents were 1.416 times more likely to have diabetes than food secure respondents.
Vozoris 2003	Cycle 2 NPHS in Canada Cross-sectional	N= 81,804 Respondents	Household food insufficient: 3-item of USDA FSSM	Self-reported diabetes	Individuals from food-insufficient households had significantly higher odds of multiple chronic conditions. Individuals in food-insufficient households were also more likely to report diabetes.
Weigel et al. 2007	California Agricultural Worker's Health Survey Cross-sectional	N= 100 migrant and seasonal farmworker (MSFW) from U.S.–Mexico border	Food insecurity: 18-item USDA FSSM	Self-reported diabetes; fasting blood glucose (>100 mg/dL)	No association

Food Insecurity and Hypertension

Holben 2006	Rural Ohio Cross-sectional	N=2580 Women and men (average 44.7y)	Household Food insecurity: 18-item USDA FSSM	Clinical measurement: diastolic blood pressure	Diastolic blood pressure did not differ by food security status (P > .05)
Parker and Widome 2010	NHANES 1999-2006 Cross-sectional	N=6138 adults N=3113 adolescents	Household food insecurity: 18-item USDA FSSM	Clinical measurement (blood pressure > 130/85 mm Hg)	Systolic blood pressure was difference by food security status
Vozoris 2003	Cycle 2 (1996/ 1997) NPHS in Canada Longitudinal and Cross-sectional	N= 81,804 Respondents	Household food insufficient: 3-item of USDA FSSM	Self-reported blood pressure condition	Individuals from food-insufficient households had significantly higher odds of multiple chronic conditions. Individuals in food-insufficient households were also more likely to report high blood pressure.
Seligman et al. 2010	NHANES 1999-2004 Cross-sectional	N=5094 Low-income adults (18-65y)	Household Food insecurity: 6-item adults USDA FSSM	Clinical measurement (SBP>140 mm Hg or DBP>90 mm Hg); self-reported use of antihypertensive medication; Self-reported hypertension	Food insecurity was associated with self-reported hypertension (ARR 1.20; 95% CI, 1.04–1.38). Food insecurity was also associated with laboratory or examination evidence of hypertension (ARR 1.21; 95% CI, 1.04–1.41)

Terrell 2009	NHANES 1999-2004 Cross-sectional	N=15,199 Adults (average 45y)	Household Food insecurity: 18-item USDA FSSM	Self-reported hypertension	There was no significant association between food secure and food insecure individuals having HTN.
Weigel et al. 2007	California Agricultural Worker's Health Survey Cross-sectional	N= 100 migrant and seasonal farmworker (MSFW) from U.S.–Mexico border	Food insecurity: 18-item USDA FSSM	Self-reported hypertension ; Clinical measurement (blood pressure ≥130/85 mmHg)	No association

Food Insecurity and Hyperlipidemia

Dixon et al. 2001	NHANES III Cross-sectional	N=10,768 adults (20-59 y) N=5143 adults (≥60 y)	Household Food insufficiency	Clinical measurement: serum total, LDL, HDL cholesterol, triglycerides	Older adults from food-insufficient families had lower serum concentrations of HDL cholesterol (p=0.03). Younger adults from food-insufficient families had lower serum concentrations of total cholesterol (p=0.05).
Holben 2006	Rural Ohio Cross-sectional	N=2580 Women and men (average 44.7y)	Household Food insecurity: 18-item USDA FSSM	Clinical measurement: total cholesterol	Total cholesterol did not differ by food security status (P > .05)
Parker and Widome 2010	NHANES 1999-2006 Cross-sectional	N=6138 adults N=3113 adolescents	Household food insecurity: 18-item USDA FSSM	Clinical measurement (TC ≥ 150 mg/ml; HDL <	No association

				40 mg/ml in men; HDL < 50 mg/ml in women)	
Seligman et al. 2010	NHANES 1999-2004 Cross-sectional	N=5094 Low-income adults (18-65y)	Household Food insecurity: 6-item adults USDA FSSM	Clinical measurement (TC ≥240mg/dL or fasting LDL≥ 160mg/dL or self-reported use of lipid-lowering therapy); Self-reported hyperlipidemia	Food insecurity was associated with self-reported hyperlipidemia (ARR 1.30; 95% CI, 1.09–1.55). The association between household food insecurity and clinical evidence of hyperlipidemia was not significant (P = 0.4).
Tayie 2009	NHANES 1999-2002 Cross-sectional	n=5549 Adults (18-50y)	Household Food insecurity: 18-item USDA FSSM	Clinical measurement (HDL, LDL, TC, TRG, and LDL/HDL, TC/HDL, TRG/HDL ratio)	Among men, food insecurity did not associate with hyperlipidemia. Marginally food secure women were more likely to have abnormal levels of LDL and TRG/HDL ratio. Women who were food insecure without hunger were more likely to have abnormal levels of TRG.
Weigel et al. 2007	California Agricultural Worker’s Health Survey Cross-sectional	N= 100 migrant and seasonal farmworker (MSFW) households living on the U.S.–Mexico border	Food insecurity: 18-item USDA FSSM	Clinical measurement (Fasting blood total cholesterol, HDL, triglycerides)	No association

2.3 Food Insecurity and Diagnosis of Chronic Conditions

2.3.1 Definition of Undiagnosed Chronic Conditions

Among studies concerning prevalence and consequences of undiagnosed chronic conditions or factors related to undiagnosed chronic conditions, the consensus definition is: clinical evidence of chronic condition to define disease presence and participants' lack of awareness of disease state based on self-report (20, 23, 25, 62-64). However, differences among studies exist because researchers have employed different criteria to clinically define chronic conditions (diabetes, hypertension and hyperlipidemia), These differences in criteria are a result of updated guidelines for the identification and treatment of diseases (14, 18, 23, 62, 63, 65-67).

For the clinicaldefinition of diabetes, some studies defined it as fasting plasma glucose (FPG) ≥ 126 mg/dl (7 mmol/L) (14, 63, 66), while some preferred FPG ≥140 mg/dl (62). Cosson et al. (67) reported large proportion of diabetes would be undiagnosed when only measuring FPG and/or HbA1c in overweight or obese patients. American Diabetes Association (65) recommended that one could be classified as having diabetes if an individual met at least one of the following three clinical evidences: 1) Casual plasma glucose concentration ≥ 200 mg/dl; or 2) FPG ≥ 126 mg/dl; or 3) 2-hour post load glucose ≥ 200 mg/dl. They also defined pre-diabetes as glucose levels do not meet criteria for diabetes, yet are higher than those considered normal (FPG= 100-125 mg/dl; or 2-hour post load glucose= 140-199 mg/dl; or A1c= 5.7-6.4%).

An overarching clinical definition of hypertension was Blood Pressure (BP) ≥ 140/90 mm Hg. More rigorous criteria might exist for some groups in analyses (e.g., it is usually defined as BP ≥ 130/80 mm Hg) (23, 63). Parker and Widome (18) used BP ≥ 130/85 mm Hg as definition of hypertension in NHANES data analysis. According to the guideline released from American

Heart Association (AHA) Task Force released in 2007, the definition of hypertension was BP ≥ 140/90 mm Hg (68).

There is no consensus clinical definition for hyperlipidemia for research purposes. Tayie and Zizza (12) defined hyperlipidemia by measuring high-density lipoprotein (HDL), low-density lipoprotein (LDL), total cholesterol (TC), triglyceride (TRG), as well as the ratio of LDL/HDL, TC/HDL, TRG/HDL, while some studies only measured TC level (7, 22, 63). The National Cholesterol Education Program (NCEP) released in 2002 report recommended the criteria as LDL-cholesterol ≥ 130mg/dl (69). Fryar et al. used total cholesterol ≥ 240 mg/dl to define hyperlipidemia in their study (63). Kompoti et al found triglycerides ≥ 150 mg/dl or HDL-cholesterol <40 for men and <50 for women were the strongest indicators for the presence of hyperlipidemia (70).

2.3.2 Prevalence and Consequences of Undiagnosed Chronic Conditions

According to an official report from CDC released in 2010, nearly half (45%) of U.S. adults (>20y) had at least one of three diagnosed or undiagnosed chronic conditions—diabetes, hypertension or hyperlipidemia based on NHANES 1999-2006 (63). More than one in seven adults (15%) had at least one undiagnosed chronic condition: 3% adults had undiagnosed diabetes, 8% adults had undiagnosed hypertension and 8% adults had undiagnosed hyperlipidemia (63).

In 2010, the prevalence of diabetes was 8.3% (25.8 million) among the U.S. population, including 7.0 million people having undiagnosed diabetes (71). Evidences indicates this prevalence has been increasing over time (71, 72). Diabetes was reported to be the leading cause of blindness, end-stage renal disease, and lower-extremity amputations, as well as a risk factor for Coronary Artery Disease (CAD) and stroke (73). Research indicates that undiagnosed diabetes is related to total mortality (Adjusted Hazard Ratio (AHR) 1.69, 95% CI 1.17-2.46) and cardiovascular mortality (AHR 2.45, 95% CI 1.58-3.81) during a 7-year follow-up (74). Since the latent stage for diabetes is likely to be long and diabetes-related complications may develop and progress prior to the time of diagnosis, undiagnosed diabetes is a major public health concern (73, 75).

As IOM reported in 2010, about 73 million Americans, nearly one third adults, had hypertension (76). Undiagnosed hypertension was the focus of this thesis because hypertension is the second leading cause of death in the United States (76). It is one of the major risk factors for CAD, strokes and renal failure, particularly when hypertension is undiagnosed (69, 77).

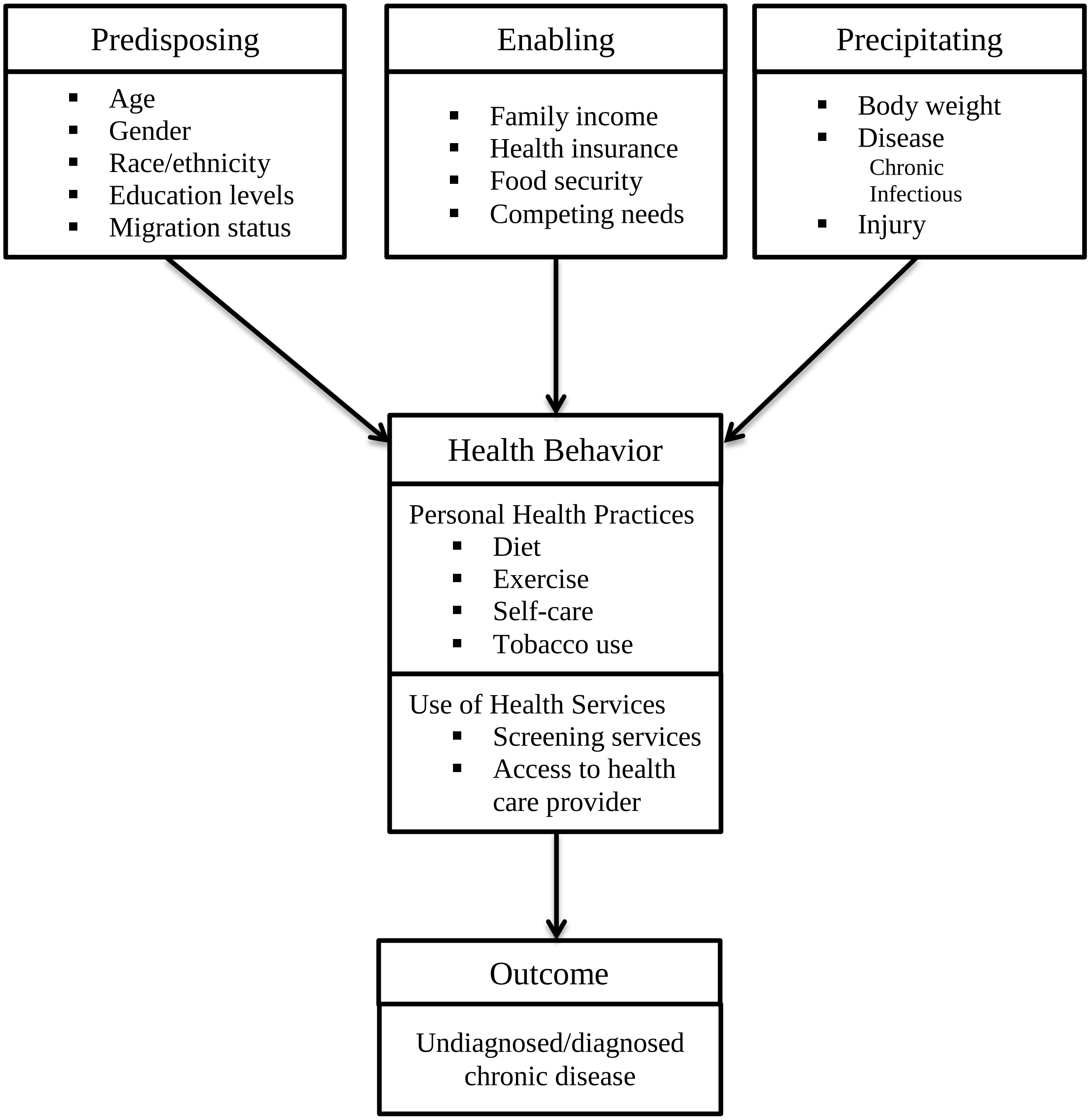
Hyperlipidemia is common among non-delderly adults. In2005-2008, about 23% adults (20-64y) had hyperlipidemia (defined as high total cholesterol) (22). Kuklina and colleagues (78) reported that among adults with elevated LDL-C levels, 36% were unscreened and 25% had been screened but not told the results during 2005-2006. Hyperlipidemia has been recognized as a major contributing factor for the initiation and progression of atherosclerosis, which can increase the risk for CAD (79), particularly when undiagnosed (69, 77).

2.3.3 Theoretical Frame Work to Explain Relationship

Several theoretical models have been proposed regarding the concept of competing priorities, which assumes that families with limited resources have to make choices among subsistence needs and health care needs (2-4). Gelberg-Andersen Behavioral Model for

Vulnerable Population (3) provides a framework of “predisposing”, “enabling” and “need” factors which influence use of health care services and ultimately health outcome. Individuals with limited resources, such as low family income, may be forced to pay for basic needs, such as food, health insurance, or other competing needs, rather than health care services (5). Gorton et al. (80) reviewed the environmental factors influencing food security, including economic, socio-cultural, and political influences on household food security. The theoretical model for relationship between food insecurity and undiagnosed chronic conditions used for this study is shown in Illustration 1.

Illustration 1. Theoretical model for relationship between food insecurity and undiagnosed chronic conditions.



Adapted from: Gelberg, 2000; Andersen, 1995

2.3.4 Factors Associated with Undiagnosed Chronic Conditions

Several factors, including demographic, socio-cultural and economic influences, have been reported to be related to undiagnosed chronic conditions (19-25). In the U.S. similar rates of having one or more of the three undiagnosed conditions (diabetes, hypertension and hyperlipidemia), were observed among adults of different races/ethnicities (63).

Individuals without insurance (OR 2.6, 95% CI 1.0-6.6) and without routine health care (OR 4.5, 95% CI 1.4-14.1) were reported more likely to have undiagnosed diabetes (19). Type of insurance, number of times receiving health care in the past year, and routine patterns of health care utilization were also associated with undiagnosed diabetes (81). Individuals with obesity were more likely to have undiagnosed diabetes (OR 1.95, 95% CI 1.01-3.76) (Wilder, 2005). However, Wee and colleagues (82) observed there was no association between obesity and undiagnosed diabetes. The prevalence of chronic kidney disease (CKD) (29.8%) was significantly higher among people with undiagnosed diabetes than those with diagnosed diabetes ($P<0.001$) (24). In elderly adults, undiagnosed diabetes was related to history of hypertension, higher BMI, and larger waist circumference (21). In other work, undiagnosed diabetes was not related to adult's education level or family income (20).

Participants with undiagnosed hypertension were more likely not to have health insurance (22, 25). Undiagnosed hypertension has also been reported related to age, gender, and access to health care (25). Adults without recent contact with a health professional (e.g., more than 5 years vs less than 1 year) were much more likely to have undiagnosed hypertension (AOR=5.28, 95% CI 2.72-10.24). Mexican American participants who used Spanish more often than English were more likely to have undiagnosed hypertension (AOR 2.2, 95% CI 1.3–3.6) (23). Undiagnosed hypertension was more likely among individuals who were young, male, and smokers, and had fewer visits to a physician, and fewer difficulties with instrumental activities of daily living (IADLs), to diagnosed hypertensive counterparts (23).

Lack of health insurance has been linked to undiagnosed hyperlipidemia among adults (22, 25). Undiagnosed hyperlipidemia was also associated with being young, Black and less access to health care (25). Adults without recent contact with a health professional were much more likely to have undiagnosed hyperlipidemia (AOR=4.76, 2.07-10.92) (25).

For all three conditions, diabetes mellitus, hypertension and hyperlipidemia, lack of health insurance, higher BMI, age, gender have been shown to be predictors of individuals knowing their disease status. Other factors, such as education level, have not been found to be related. One interesting point is that income was related to undiagnosed hyperlipidemia but was not related to undiagnosed diabetes mellitus.

Chapter 3 Adult Food Insecurity and Undiagnosed Chronic Conditions

3.1 Abstract

The purpose of this thesis is to examine the relationship between food insecurity and undiagnosed chronic conditions, including prediabetes, hypertension and hyperlipidemia, among adults (20-64y). Food security status was assessed by the ten items for adults from Food Security Survey Module. Undiagnosed chronic conditions were determined by comparing self-reported information with clinical examination evidence. The clinical definition for prediabetes was fasting plasma glucose = 100-125 mg/dl or A1C =5.7-6.4%, for hypertension was blood pressure ≥ 140/90 mm Hg, and hyperlipidemia was defined by several criteria, including triglyceride, LDL, HDL and total cholesterol. Food insecure adults was more likely to have undiagnosed prediabetes (odds ratio 1.49, 95% CI 1.17-1.88). The relationship between food insecurity and undiagnosed hypertension and hyperlipidemia no longer existed after adjusting for confounding variables. These results indicate that food insecure adults may not know their risk status for diabetes. Screening for diabetes in food insecure populations appears to be warranted.

3.2 Introduction

Throughout 2010, an estimated 32.6 million adults in US were considered food insecure (1), which means "the availability of nutritionally adequate and safe foods or the ability to acquire acceptable foods in socially acceptable ways is limited or uncertain" (2). In food insecure households, individuals reported that it was difficult at some time during the year to provide enough food for all members due to a lack of money and other resources (1). Several theoretical models have been proposed regarding the concept of competing priorities, which assumes that families with limited resources have to make choices among subsistence needs and health care needs (2-4). Individuals with limited resources, such as low family income, may be forced to pay for basic needs, such as food, health insurance, or other competing needs, rather than health care services (5).

The consequences of food insecurity include hunger, malnutrition, and poor physical health and overall quality of life either directly or indirectly through nutritional status (43). Chronic conditions, including diabetes, hypertension and hyperlipidemia have reported to be risk factors of increasing coronary artery disease, particularly when undiagnosed (69, 73, 76, 77, 79).

There were no study examining relationship between food insecurity and undiagnosed diabetes, hypertension and hyperlipidemia. Food insecure individuals were reported significantly more likely to have multiple chronic conditions (13).Of the previous studies examining the relationship between food insecurity and diabetes, most studies found positive relationships (6-11, 14). Seligman et al. observed food insecurity was associated with clinical evidence of diabetes, but not with self-reported diabetes (14). Previous studies about relationship between food insecurity with hypertension and hyperlipidemia are not consistent, that is some found an association, some reported not (7, 10-12, 14, 16-18).

The purpose of this study is to examine the relationship between food insecurity and undiagnosed chronic conditions, including prediabetes, hypertension and hyperlipidemia, among non-elderly adults (20-64y) in the United States. Efforts to control and reduce the prevalence of chronic disease may be more effective when they are initiated early during the progression of these conditions. For this reason prediabetes, hypertension and hyperlipidemia are highlighted in this study. The data used for this purpose were from National Health and Nutritional Examination Survey (NHANES) 1999-2008 and logistic regression models were conducted to estimate the relationship separately.

3.3 Methods and Procedures

3.3.1 Study Sample

The present study is based on five cycles of the continuous NHANES 1999-2000, 2001-2002, 2003-2004, 2005-2006 and 2007-2008 (NHANES 1999-2008). The NHANES are cross-sectional nationally representative health and nutrition surveys of the noninstitutionalized U.S. civilian population aged 2 months and older. The NHANES are conducted by the National Center for Health Statistics (NCHS), Centers for Disease Control and Prevention (CDC), using a stratified, multistage probability cluster design with oversampling of minorities, children, and the elderly. Sampling and survey design information were described in detail elsewhere (83). Data are released in a two-year cycle to protect confidentiality and increase statistical reliability. The surveys consist of interviewer-administered questionnaires conducted in participants' homes, standardized physical examinations conducted in specially equipped Mobile Examination Centers (MECs), and laboratory tests utilizing blood and urine specimens provided by participants during the physical examination (34).

Individuals under 20 years were excluded in our study because of low prevalence of chronic diseases. Elderly adults (> 65y) were also excluded, because age is a strong predictor and chronic conditions are great higher among elderly adults. We excluded pregnant and lactating women who had positive laboratory pregnancy test or self-reported pregnant and self-reported lactating, because pregnancy and lactating may affect some clinical variables used to determine undiagnosed chronic conditions. After checking the availability of data on age, BMI, PIR, sex, race, health insurance status, education levels, clinic laboratory tests and self-reported questionnaire about chronic conditions, the analytical sample sizes for estimating the relationships between food security status and undiagnosed prediabetes, hypertension, and hyperlipidemia were 10775, 13194 and 10721, respectively.

The protocols of the survey were approved by NCHS Ethics Review Board and informed consent was obtained from all subjects (84). The protocol for our study was approved by the Institutional Review Board, Office of Human Subjects Research, Auburn University.

3.3.2 Measurement of Food Insecurity

Food and Nutrition Service in USDA has been using a stable, robust, and reliable 18-item Household Food Security Survey Module (FSSM) at household level. The FSSM is based on the LSRO concept of food insecurity which occurs whenever the availability of nutritionally adequate and safe foods or the ability to acquire acceptable foods in socially acceptable ways is limited or uncertain (2, 27, 30). One adult in a household was interviewed and the questions referred to all household members. Adult food security status was measured by ten items from the 18-item FSSM. Adult food security status was assigned to food security categories as fully food security (reported yes to none of the items), marginal food security (responded yes to 1-2 items), low food security (responded yes to 3-5 items) and very low food security (responded yes to 6-10 items) (85, 86). These categories were the same as those used for the household measure, but they utilized only household and adult items (85, 86).

3.3.3 Measurement of Undiagnosed Chronic Conditions

An undiagnosed chronic condition is defined by comparing clinical evidence to self-reported information (62, 63, 72). The definition of undiagnosed chronic conditions is shown in Table 3. In questionnaire file from NHANES 1999-2008, participants were interviewed regarding whether or not they have been told by health care provider that they had a chronic condition. The clinical evidence to determine disease status was obtained from MEC examination data file and laboratory data file. Laboratory component data included findings from analyses of blood samples collected from participants.

3.3.3.1 Measurement of Undiagnosed Prediabetes

During the household interview participants were asked whether a doctor or health care professional had ever told them they had any of the following: prediabetes, impaired fasting glucose, impaired glucose tolerance, borderline diabetes or blood sugar is higher than normal but not high enough to be called diabetes or sugar diabetes. Clinical evidences are based on concentrations of fasting plasma glucose and the percentage of blood glycohemoglobin (A1C) was obtained from NHANES laboratory file. The fasting glucose blood test was performed on participants who were examined in the morning session, after a 9 hour fast(87). Concentration of fasting plasma glucose was examined by a hexokinase method and it is an endpoint enzymatic method that is specific for glucose. Glycated proteins differ from non-glycated proteins by the attachment of a sugar moiety(s) at various binding sites by means of a ketoamine bond. Glycohemoglobin thus contains 1,2-cis-diol groups not found in non-glycated proteins, which could be separated and determined by boronate affinity high performance liquid chromatography(87). Reference clinical guidelines according to American Diabetes Association are used to identify prediabetes as the following criteria: fasting plasma glucose between 100 mg/dL (5.6 mmol/L) to 125 mg/dL (6.9 mmol/L); or an A1C from 5.7% to 6.4% (65) (Table 3). We excluded participants who had diabetes, determined with either self-reported diabetes or clinical evidence on diabetes (plasma glucose concentration ≥ 200 mg/dl; or fasting plasma glucose ≥ 126 mg/dl; or 2-hour post load glucose ≥ 200 mg/dl; or A1C ≥ 6.5 %). The undiagnosed prediabetes was determined by comparing self-reported prediabetes status with clinical examination determinants. Subjects were categorized into undiagnosed prediabetes if they had clinical indicators of prediabetes but were currently not aware or not diagnosed by a doctor or health care professional, otherwise subjects were assigned into non-undiagnosed prediabetes category.

3.3.3.2 Measurement of Undiagnosed Hypertension

Another outcome variable is the undiagnosed hypertension. Participants were interviewed whether they had ever been told by a doctor or other health professional that they had hypertension, also called high blood pressure. All blood pressure determinations (systolic and diastolic) were measured in MECs for 4 attempts using a mercury sphygmomanometer. After resting 5 minutes for the first attempt, 2 consecutive blood pressure readings were obtained from participants. A fourth measure might be taken if the measurements of blood pressure are interrupted or incomplete (88). In order to use the accurate blood pressure reading from participants in our analysis, we dropped the first reading and used the average the other reading(s), if there is more than one measurement. If only one measurement was available, that reading was used in the study. Clinic hypertension in our study was defined as BP ≥ 140/90 mm Hg according to the Seventh report of the Joint National Committee on Prevention, Detection, Evaluation, and Treatment of High Blood Pressure (77). The undiagnosed hypertension was determined by comparing self-reported hypertension status with clinical examination determinants. Subjects were categorized into undiagnosed hypertension if they had clinical high blood pressure but were currently not aware or not diagnosed by a doctor or health care professional.

3.3.3.3 Measurement of Undiagnosed Hyperlipidemia

The third outcome variable is undiagnosed hyperlipidemia. Participants were asked during the household interview that whether they were ever told they had high blood cholesterol level by a doctor or other health professional. Serum cholesterol levels were tested only on participants who fasted at least 8.5 hours or more but less than 24 hours examined in the morning session (89). In an enzymatic method, esterified cholesterol was converted to cholesterol by cholesterol esterase (90). Trinder reaction was used as the final step to produce a colored product which could be measured at 505 nm and it was specific for cholesterol (90). HDL-cholesterol was determined by a PEG enzymatic method specific for HDL-cholesterol (90). Triglycerides are fatty acid esters of glycerol that have three hydroxyl groups, a two-reagent enzymatic method was conducted specific for measuring triglycerides (89). LDL-cholesterol was calculated from measured values of total cholesterol, triglycerides, and HDL-cholesterol according to the Friedewald calculation: [LDL-cholesterol] = [total cholesterol] – [HDL-cholesterol] – [triglycerides/5] (89). The criteria used to define hyperlipidemia are as follows: LDL-cholesterol ≥ 130 mg/dl (69); or total cholesterol ≥ 240 mg/dl (63); or triglycerides ≥ 150 mg/dl (70); or

HDL-cholesterol <40 mg/dl for men and <50 mg/dl for women (70) (Table 3). The undiagnosed hyperlipidemia was determined by comparing self-reported hyperlipidemia status with clinical determinants. Subjects were categorized into undiagnosed hyperlipidemia if they had clinical high levels of blood lipids but were currently not aware or not diagnosed by a doctor or health care professional.

Table 3 Definition of undiagnosed chronic conditions

Undiagnosed chronic conditions	Self-reported condition	Clinical evidence of condition
Undiagnosed prediabetes	Not being told by a doctor or health care professional that they had prediabetes	1) Fasting plasma glucose= 100-125 mg/dl; or 2) A1C=5.7-6.4%
Undiagnosed hypertension	Not being told by a doctor or health care professional that they had hypertension	BP ≥ 140/90 mm Hg
Undignosed hyperlipidemia	Not being told by a doctor or health care professional that they had hyperlipidemia	1) LDL-cholesterol ≥ 130 mg/dl; or 2) total cholesterol ≥ 240 mg/dl; or 3) triglycerides ≥ 150 mg/dl; or 4) HDL-cholesterol <40 mg/dl for men and <50 mg/dl for women

Sources: American Diabetes Association, 2011; Fryar, 2010; Chobanian, 2003; NCEP Expert Panel, 2001; Kompoti, 2006.

3.3.4 Statistical Analysis and Confounding Variables

All estimates were weighted to account for the unequal probability of selection that resulted from the survey cluster design, nonresponse, and oversampling of certain target population (91, 92). MEC examinations weighting variable were used for these analyses. Because Decennial Census counts to estimate population developed by the Bureau of the Census became available in 2000, combining NHANES 1999-2000 with 2001-2002 must use the 4-year sample weights provided by NCHS since these were created to account for difference population bases for NHANES 1999-2000 and later years (93). To analyze NHANES 1999-2008, a ten year weight was needed, which was 2/5 of the 4-year MEC weight for NHANES 1999-2002 and 1/5 of the 2-year MEC weight for NHANES 2003-2008. Data were analyzed using SAS 9.2 software (SAS Institute Inc., Cary, NC). NHANES 1999-2000, 2001-2002, 2003-2004, 2005-2006 and 2007-2008 data files were merged to obtain the study sample. Descriptive statistics were used to depict background characteristics of participants categorized by food security status. Odds ratios (OR) were estimated by logistic regression models for the relationship between food insecurity and undiagnosed prediabetes, hypertension and hyperlipidemia, with full food security as referent group at $P < 0.05$ significant level.

Confounding variables included in the logistic regression models were age, BMI, poverty income ratio (PIR), sex, race/ethnicity, health insurance status and education levels. In our study, age, BMI and levels and PIR were continuous variables. PIR was used to present poverty status as it is an index calculated by dividing family income by an annually poverty threshold specific to family size (94). According to the guidelines of NHANES analyses that sample sizes were small for some race/ethnic groups, race/ethnicity was categorized to Mexican-American and others, non-Hispanic White, and non-Hispanic Black (91, 92). Health insurance status was obtained from the household questionnaires and reflected whether the participants were covered by health insurance or some other type of health care plan including health insurance obtained through employment or purchased directly as well as government programs such as Medicare and Medicaid. Education levels were collapsed into two categories: less than high school and high school or equivalent or higher degree.

3.4 Results

3.4.1 Sample Characteristics

Socio-demographic, economic and undiagnosed chronic condition characteristics of subjects in the three different chronic condition subsamples were presented in Table 4, 5, 6. The smallest sample size was for the hyperlipidemia analysis (N=10721). In each chronic condition subsample, 12.21% individuals had undiagnosed prediabetes (Table 4), 6.07% had undiagnosed hypertension (Table 5) and 22.67% had undiagnosed hyperlipidemia (Table 6).

3.4.2 Adults Food Security Status and Undiagnosed Chronic Conditions

Results of the association between food security status and undiagnosed chronic conditions are presented in Table 7 (crude value) and Table 8 (adjusted value). Overall, food security status had relationship with undiagnosed chronic conditions, but the relationship was not consistent.

Undiagnosed prediabetes was significantly related to food security status among adults (P<0.05) (Table 7, 8). Both marginal food security and low and very low food security were more likely to have undiagnosed prediabetes (odds ratio (OR) 1.45, 95% CI 1.18-1.78; OR 1.49, 95% CI 1.17-1.88) (Table 8). In the crude analysis, the odds of undiagnosed prediabetes was

1.34 (95% CI 1.11-1.62) for those with marginal food security and 1.25 (95% CI 1.03-1.53) for those with low and very low food security (Table 7).

Undiagnosed hypertension was not significantly related to either marginal food security (OR 0.96, 95% CI 0.70- 1.29) or low and very low food security (OR 0.85, 95% CI 0.69- 1.04) in the crude analysis. After controlling for confounding variables, there were also no significant relationship between food security status and undiagnosed hypertension, with an odds ratio of 0.94 for marginal food secure adults (95% CI 0.69- 1.28) and 0.83 for those who were low and very low food security (95% CI 0.66- 1.04) (Table 8).

Undiagnosed hyperlipidemia was linked to low and very low food security in the crude model (OR 0.81, 95% CI 0.68 0.96) (Table 7). There was no significant relationship between adult food secure categories and undiagnosed hyperlipidemia after confounding for confounding variables (Table 8).

Table 4.Characteristics of adult participants (20-64y) by food security status, NHANES 1999-2008

Characteristic	Fully food security (n= 8245)	Marginal food security (n= 1034)	Low and very low food security (n= 1496)	Sample Total (N=10775)
		mean ±SE		
Age in y	40.83± 0.25	36.11± 0.39	36.30± 0.40	40.09± 0.21
BMI (kg/m^2)	27.56± 0.10	28.78± 0.28	28.03± 0.28	27.68± 0.09
PIR [1]	3.50± 0.04	1.78± 0.07	1.43± 0.04	3.19± 0.04
		Percentage (%)		
Sex				
Men	49.15	47.37	49.78	49.09
Women	50.85	52.63	50.22	50.91
Race				
Non-Hispanic White	83.72	54.23	58.83	79.42
Non-Hispanic Black	10.01	23.48	20.56	11.90
Mexican American[2]	6.27	22.29	20.61	8.68
Health insurance				
Covered	83.87	58.17	53.29	79.29
Not covered	16.13	41.83	46.71	20.71
Education				
≥ High school	88.54	70.68	63.86	85.03
< High school	11.46	29.32	36.14	14.97
Undiagnosed prediabetes	11.70	15.06	14.76	12.21

Sample used for the undiagnosed prediabetes analyses. All values were weighted and design corrections were applied to represent the non-pregnant and non- lactating population of non-elderly adults (20-64y). Participants had complete data regarding age, BMI, PIR, sex, race health insurance, education and prediabetes information.

1 Poverty income ratio, an index calculated by dividing family income by an annually poverty threshold specific to family size (94).

2 Including other Hispanics.

Table 5. Characteristics of adult participants (20-64y) by food security status, NHANES 1999-2008

Characteristic	Fully food security (n= 10073)	Marginal food security (n= 1224)	Low and very low food security (n= 1897)	Sample Total (N= 13194)
	mean ±SE			
Age in y	42.23± 0.24	38.14± 0.44	38.22± 0.40	41.57± 0.20
BMI (kg/m^2)	28.24± 0.11	29.63± 0.27	28.86± 0.27	28.39± 0.10
PIR [1]	3.50± 0.04	1.77± 0.06	1.39± 0.04	3.18± 0.04
	Percentage (%)			
Sex				
Men	51.11	48.59	50.28	50.87
Women	48.89	51.41	49.72	49.13
Race				
Non-Hispanic White	82.88	53.54	59.59	78.70
Non-Hispanic Black	10.57	23.64	20.36	12.38
Mexican American [2]	6.55	22.82	20.05	8.92
Health insurance				
Covered	84.02	59.68	55.18	79.62
Not covered	15.98	40.32	44.82	20.38
Education				
≥ High school	87.37	69.74	61.47	83.68
< High school	12.63	30.26	38.53	16.32
Undiagnosed hypertension	6.18	5.91	5.28	6.07

Sample used for the undiagnosed hypertension analyses. All values were weighted and design corrections were applied to represent the non-pregnant and non- lactating population of non-elderly adults (20-64y). Participants had complete data regarding age, BMI, PIR, sex, race health insurance, education and hypertension information.

1 Poverty income ratio, an index calculated by dividing family income by an annually poverty threshold specific to family size (94).

2 Including other Hispanics.

Table 6. Characteristics of adult participants (20-64y) by food security status, NHANES 1999-2008

Characteristic	Fully food security (n= 8452)	Marginal food security (n= 888)	Low and very low food security (n= 1381)	Sample Total (N=10721)
		mean ±SE		
Age in y	43.41± 0.25	39.39± 0.55	39.33±0.44	42.83± 0.22
BMI (kg/m^2)	28.20± 0.12	29.52± 0.33	28.99±0.30	28.35±0.11
PIR [1]	3.63± 0.04	1.87±0.075	1.44±0.04	3.34± 0.04
		Percentage (%)		
Sex				
Men	50.22	48.55	48.55	49.98
Women	49.78	51.45	51.45	50.02
Race				
Non-Hispanic White	83.93	56.55	60.64	80.37
Non-Hispanic Black	10.33	24.29	21.84	12.12
Mexican American [2]	5.73	19.16	17.52	7.51
Health insurance				
Covered	86.73	64.52	58.29	83.02
Not covered	13.27	35.48	41.71	16.98
Education				
≥ High school	88.84	72.15	64.76	85.82
< High school	11.16	27.85	35.24	14.18
Undiagnosed hyperlipidemia	23.05	21.81	19.49	22.67

Sample used for the undiagnosed hyperlipidemia analyses. All values were weighted and design corrections were applied to represent the non-pregnant and non- lactating population of non-elderly adults (20-64y). Participants had complete data regarding age, BMI, PIR, sex, race health insurance, education and hyperlipidemia information.

1 Poverty income ratio, an index calculated by dividing family income by an annually poverty threshold specific to family size (94).

2 Including other Hispanics

Table 7.Relationship of food security status to undiagnosed chronic conditions among adult (20-64y) without adjustment, NHANES 1999-2008

	Undiagnosed prediabetes OR (n= 10775)	Undiagnosed hypertension OR (n= 13194)	Undiagnosed hyperlipidemia OR (n= 10721)
Full food security	1.00	1.00	1.00
Marginal food security	1.34 (1.11 1.62)	0.96 (0.70 1.29)	0.93 (0.75 1.17)
Low and very low food security	1.25 (1.03 1.53)	0.85 (0.69 1.04)	0.81 (0.68 0.96)

All values are weighted and design corrections are applied to represent the non-pregnant and non- lactating population of the US adults. Odds ratios (OR) were estimated by logistic regression models for the relationship between food insecurity and undiagnosed diabetes, hypertension and hyperlipidemia, with full food security as referent group at P< 0.05 significant level.

Table 8.Relationship of food security status to undiagnosed chronic conditions among adult (20-64y) after adjustment, NHANES 1999-2008

	Undiagnosed prediabetes OR (n= 10775)	Undiagnosed hypertension OR (n= 13194)	Undiagnosed hyperlipidemia OR (n= 10721)
Full food security	1.00	1.00	1.00
Marginal food security	1.45 (1.18 1.78)	0.94 (0.69 1.28)	0.94 (0.74 1.19)
Low and very low food security	1.49 (1.17 1.88)	0.83 (0.66 1.04)	0.84 (0.68 1.03)
Age in y	1.05 (1.05 1.06)	1.04 (1.03 1.05)	1.00 (1.00 1.01)
BMI (kg/m^2)	1.07 (1.06 1.08)	1.02 (1.01 1.03)	1.06 (1.05 1.07)
PIR [1]	1.05 (0.98 1.13)	0.99 (0.92 1.05)	1.00 (0.95 1.05)
Women	0.61 (0.54 0.67)	0.56 (0.46 0.67)	1.05 (0.93 1.18)
Non-Hispanic Black	1.45 (1.07 1.98)	1.38 (1.13 1.68)	0.65 (0.57 0.75)
Mexican American [2]	1.51 (1.05 2.18)	1.02 (0.82 1.26)	0.88 (0.73 1.05)
No health insurance	1.30 (1.09 1.55)	1.37 (1.09 1.72)	0.88 (0.77 1.02)
Educ < High school	1.15 (0.91 1.44)	1.09 (0.88 1.35)	0.98 (0.86 1.13)

All values are weighted and design corrections are applied to represent the non-pregnant and non- lactating population of the US adults. Odds ratios (OR) were estimated by logistic regression models for the relationship between food insecurity and undiagnosed diabetes, hypertension and hyperlipidemia at P< 0.05 significant level. Age, BMI and PIR are continuous and the referent groups for category variables are: full food security, men, non-Hispanic White, having health insurance, and education level of high school degree or more.

1 Poverty income ratio, an index calculated by dividing family income by an annually poverty threshold specific to family size (94).
2 Including other Hispanic

3.5 Discussion

Our study is the first, to our knowledge, to examine the relationship between food insecurity and undiagnosed chronic conditions, including undiagnosed prediabetes, hypertension and hyperlipidemia. A significant finding in this study is that adults with marginal food security and with low and very low food security were more likely to have undiagnosed prediabetes. Of the previous studies examining the relationship between food insecurity and diabetes, most studies found food insecure adults were more likely to be diabetic (6-11, 14). Interestingly, Seligman et al. observed food insecurity was associated with clinical evidence of diabetes, but not with self-reported diabetes (14). Their study supports our observation that food insecure individuals are less likely to be aware of their risk for diabetes.

The observed positive relationship between food insecurity and undiagnosed prediabetes implies that food insecure individuals could be a vulnerable group of undiagnosed prediabetes, who might have poor health behavior of both personal health practices and use of health services. As prediabetes is a consequent stage leading diabetes and high risk to develop CAD if blood glucose keeps increasing without being controlled (65), it is important to determine vulnerable groups of undiagnosed prediabetes. There are underlying mechanisms whereby food insecure adults are more likely to have undiagnosed prediabetes. One possibility for this relationship is that individuals with limited resources, such as low family income, may be forced to pay for basic needs, such as food, health insurance, or other competing needs, rather than seeking health care services.

On the other hand, we did not find relationship between food insecurity and undiagnosed hypertension and hyperlipidemia after adjusting for confounders. These results suggest that undiagnosed hypertension and hyperlipidemia may be affected by other factors, such as age and

BMI. Previous studies examining the relationship between food insecurity and hypertension and hyperlipidemia, have not yielded consistent (7, 10-12, 14, 16-18). The relationship between food insecurity and undiagnosed prediabetes exists, but not with undiagnosed hypertension and hyperlipidemia. One possibility is the latent period for diabetes, especially type 2 diabetes, may be longer than that of hypertension and hyperlipidemia. Consequently the longer latency period allows prediabetes to be observed more frequently.

There are several strengths of this study. First, this study uses both self-report and clinical examination to measure chronic conditions. Clinical based measurements are expensive, which may not be included in previous studies. Second, food security status considers a 12-month period to improve sensitivity and reliability of food security measurement, which can avoid changes between different period of time, such as months and seasons (37). In addition, the sample of this study is representative to non-institutionalized US civilians.

The limitations of our study are that we use only both fasting plasma glucose and A1C as measurement of clinical evidence of prediabetes because of the unavailability of oral glucose tolerance test in NHANES 1999-2004, which may underestimate prediabetes among patients who are overweight or obese (67). Because of the sampling design of NHANES, homeless individuals are not included in the analysis. Our study is based on cross-sectional data using regression models which do not permit an effect-causal relationship (58). Further study is needed to determine the mechanism of relationship between food insecurity and undiagnosed chronic conditions.

3.6 Conclusion

The association between food insecurity with undiagnosed prediabetes was significant, but not with undiagnosed hypertension and hyperlipidemia. These results indicate that food insecure adults may be unaware of their risk status for diabetes. Screening for diabetes for all adults, especially those who are food insecure, appear to be warranted. These findings have important practical implications for federal programs and private organizations that serve food insecure populations. Screening initiatives within federal programs, such as the Supplemental Nutrition Assistance Program, are needed.

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Appendix 1. Questions used to assess household food security in the CPS food security supplement (USDA, 2011)

1. "We worried whether our food would run out before we got money to buy more." Was that often, sometimes, or never true for you in the last 12 months?

2. "The food that we bought just didn't last and we didn't have money to get more." Was that often, sometimes, or never true for you in the last 12 months?

3. "We couldn't afford to eat balanced meals." Was that often, sometimes, or never true for you in the last 12 months?

4. In the last 12 months, did you or other adults in the household ever cut the size of your meals or skip meals because there wasn't enough money for food? (Yes/No)

5. (If yes to question 4) How often did this happen—almost every month, some months but not every month, or in only 1 or 2 months?

6. 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)

7. In the last 12 months, were you ever hungry, but didn't eat, because there wasn't enough money for food? (Yes/No)

8. In the last 12 months, did you lose weight because there wasn't enough money for food? (Yes/No)

9. In the last 12 months did you or other adults in your household ever not eat for a whole day because there wasn't enough money for food? (Yes/No)

10. (If yes to question 9) How often did this happen—almost every month, some months but not every month, or in only 1 or 2 months?

(Questions 11-18 were asked only if the household included children age 0-17)

11. "We relied on only a few kinds of low-cost food to feed our children because we were running out of money to buy food." Was that often, sometimes, or never true for you in the last 12 months?

12. "We couldn't feed our children a balanced meal, because we couldn't afford that." Was that often, sometimes, or never true for you in the last 12 months?

13. "The children were not eating enough because we just couldn't afford enough food." Was that often, sometimes, or never true for you in the last 12 months?

14. In the last 12 months, did you ever cut the size of any of the children's meals because there wasn't enough money for food? (Yes/No)

15. In the last 12 months, were the children ever hungry but you just couldn't afford more food? (Yes/No)

16. In the last 12 months, did any of the children ever skip a meal because there wasn't enough money for food? (Yes/No)

17. (If yes to question 16) How often did this happen—almost every month, some months but not every month, or in only 1 or 2 months?

18. In the last 12 months did any of the children ever not eat for a whole day because there wasn't enough money for food? (Yes/No)