ASSOCIATIONS BETWEEN ADULT FOOD INSECURITY AND VARIOUS NUTRITIONAL OUTCOMES

Except where reference is made to the work of others, the work described in this dissertation is my own or was done in collaboration with my advisory committee. This dissertation does not include proprietary or classified information.

Francis Ayisi Kwame Tayie

Certificate of Approval:

Doug White Associate Professor Nutrition and Food Science	Claire A. Zizza, Chair Assistant Professor Nutrition and Food Science
Robin Fellers Associate Professor Nutrition and Food Science	George T. Flowers Interim Dean Graduate School

ASSOCIATIONS BETWEEN ADULT FOOD INSECURITY AND VARIOUS NUTRITIONAL OUTCOMES

Francis Ayisi Kwame Tayie

A Dissertation

Submitted to

the Graduate Faculty of

Auburn University

in Partial Fulfillment of the

Requirements for the

Degree of

Doctor of Philosophy

Auburn, Alabama
August 9, 2008

ASSOCIATIONS BETWEEN ADULT FOOD INSECURITY AND VARIOUS NUTRITIONAL OUTCOMES

Francis Ayisi Kwame Tayie

____
Signature of Author

____
Date of Graduation

DISSERTATION ABSTRACT

ASSOCIATIONS BETWEEN ADULT FOOD INSECURITY AND VARIOUS NUTRITIONAL OUTCOMES

Francis Ayisi Kwame Tayie

Doctor of Philosophy, August 9, 2008
(M.S., Iowa State University, 2004)
(M.Phil., University of Ghana, 1994)
(B.Sc., University of Ghana, 1986)

135 Typed Pages

Directed by Claire A. Zizza

The purpose of this dissertation is to provide a better understanding of the health and nutritional status of food insecure persons in the United States. This dissertation covers three studies which used data from the National Health and Nutrition Examination Surveys 1999-2002. The first study determined the associations between adult food insecurity and percent body fat (%BF), BMI and height, and %BF and BMI stratified by height. Bioelectrical impedance analysis was used to determine percent body fat for 2,117 men and 1,909 women. Results showed that, among men, %BF, height and BMI decreased as food insecurity (FI) increased. Marginal food security among women who were below median height associated with about 2.0 kg/m^2 increase in BMI compared with their fully food secure counterparts, P = 0.042. Marginal food security among women associated with 1.3 cm decrease in height, $P = 0.016$. Percent body fat did not associate with food insecurity among women irrespective of height. The second study determined the associations between adult food insecurity and body weight change among 2,626 men and 2,685 women in 1 and 10 years using different specifications. Results showed that compared with the fully food secure, food insecurity among women associated with significant weight gain at both the >5kg and >10kg specifications in both 1 and 10 years. Food insecurity associated with higher prevalence of weight gain ≥10% of body weight 1 year ago among women and 10 years ago among men. Food insecurity without hunger among women associated with greater likelihood to gain >5kg of weight in 1 year. The third study estimated the probabilities of dyslipidemia and elevated plasma glucose (EPG) in relation to food insecurity among 2,572 men and 2,976 women. Results showed that, compared with the fully food secure, significantly higher percentage of marginally food secure women and food insecure without hunger women associated with dyslipidemia. Marginally food security and food insecurity without or with hunger among women associated with dyslipidemia. It was concluded that, among men, food insecurity without and with hunger associate with decreases in height, percent body fat and BMI. Among women, intermediate-level food insecurity associates with increased BMI, decreased height, greater weight gain and dyslipidemia. These results highlight the need to re-invigorate public health efforts towards improvement of food security and alleviate its effects both in the short and long term in the United States.

ACKNOWLEDGEMENTS

My heartfelt gratitude goes to Dr. Claire A. Zizza, my major advisor, for her invaluable guidance, dedication, encouragement and support throughout the course of the study. I very much thank Dr. Douglas White for guidance and additional help during this study. I express my deepest gratitude to my program committee members: Dr. Claire Zizza, Dr. Douglas White, Dr. Robin Fellers and Dr. Stephen Shumate for their time, constructive suggestions and commitment to my study. The genial atmosphere during meetings is greatly appreciated. I am thankful to Dr. Patricia Duffy for technical assistance. I am grateful to my wife, Rita Appiah and son, Kwabena Archer Taye, for their patience, understanding and motivation during my busy hours. Finally, I extend my profound gratitude and thanks to my uncle, Francis Abeka, for parental guidance and support during the course of this study. The congenial atmosphere of Auburn University is greatly appreciated.

Style manual or journal format used: Journal of Nutrition.

Computer software used: Microsoft office suite 2007, STATA for Windows 10.0 and SAS for windows version 9.1.3

TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

%BF: Percent body fat

ADA: American Dietetic Association

ADP: Adenosine diphosphate

AHA: American Heart Association

BIA: Bioelectrical impedance analysis

BMI: Body mass index

CCHIP: Community childhood hunger identification project

CDC: Centers for Disease Control

CHD: Coronary heart disease

CPS: Current population survey

CSFII: Continuing survey of food intake by individuals

CVD: Cardiovascular disease

DHHS: United States Department of Health and Human Services

EPG: Elevated plasma glucose

FASEB: Federation of American Societies for Experimental Biology

FFM: Fat-free mass

FI: Food insecurity

FSS: Food security supplement

FSSM: Food security survey module

G-6-P: Glucose-6-phosphate

G-6-PD: Glucose-6-phosphate dehydrogenase

HDL-C:	High-density lipoprotein cholesterol
Hisp	Hispanic
IHD:	Ischemic heart disease
LDL-C:	Low-density lipoprotein cholesterol
LSRO:	Life Science Research Office
MEC:	Mobile examination center
NAD:	Nicotinamide adenine dinucleotide
NADH:	Reduced nicotinamide adenine dinucleotide
NCEP:	National cholesterol education program
NCHS:	National Center for Health Statistics
NHANES:	National health and nutrition examination survey
NHLBI:	National Heart Lung and Blood Institute
NIDDKD:	National Institute of Digestive and Diabetes and Kidney Diseases
NNMRRP:	National nutrition monitoring and related research program
OB:	Overweight and obesity
OR:	Odds ratio
TBW:	Total body water
TC:	Total cholesterol
TG:	Triglycerides
USAID:	United States Agency for International Development
USDA:	United States Department of Agriculture
y:	Year

CHAPTER 1

GENERAL INTRODUCTION

During this decade 9.5 - 11.9% of adults in the United States were classified as food insecure (USDA, 2007). That is, they have limited or uncertain availability of nutritionally adequate and safe foods or limited or uncertain ability to acquire acceptable foods in socially acceptable ways (Anderson, 1990; LSRO, 1989). This level of food insecurity warrants concern because the adverse associations of food insecurity include many debilitating diseases.

Food insecurity associates with poor diet and subsequently poor health (Sharkey, 2003; Vozoris and Tarasuk, 2003; Alaimo and others, 2001). Food insecurity associates with cardiovascular disease (CVD) including coronary heart disease (CHD) stroke and hypertension, as well as type 2 diabetes, food allergy, anxiety and worry, and decreased work performance (Hampton, 2007; Stuff and others, 2004; Hamelin and others, 1999). Food insecurity may associate with CVD through associations with dyslipidemia and elevated blood glucose (EPG).

Many reports indicate that intermediate-level food insecurity associates with overweight and obesity (OB) in the United States (Wilde and Peterman, 2006; Adams and others, 2003; Townsend and others, 2001) and hence predisposes those affected to obesity-related diseases including kidney and gall bladder disease, arthritis, physical and psychosocial distress, CVD and type 2 diabetes (Kaleta and others, 2005; Lee and others, 2004). Overweight and obesity are the result of a combination of long-term energy imbalance due to excess calorie consumption and sedentary lifestyle (Koplan and Dietz, 1999), characteristics which are common among food insecure persons (Kaiser and others, 2002). The association between food insecurity and OB has been attributed to disordered eating patterns, greater preference for high-calorie foods, preoccupation with food and eating, poor weight management practices, socio-economic deprivation, lack of access to resources, and restricted physical activity (Kaiser and others, 2002; Tarasuk, 2001; Frongillo and others, 1997).

Studies that reported associations between food insecurity and OB applied BMI guidelines of the National Heart Lung and Blood Institute (NHLBI) expert panel (NHLBI Expert Panel, 2000). Even though BMI is easy to measure, suitable for most age groups and highly correlates with body fatness, morbidity and mortality (Aronne, 2002; Bray, 1996; NIDDKD, 1996), it is an indirect measure of adiposity (Snijder and others, 2006; Aronne and Segal, 2002). As such, certain people who are overweight by BMI standards do not have excess body fat, and others who have BMI within the normal range may have high percent body fat (Martins and others, 2004; Deurenberg and others, 1998; NIDDKD, 1996). In cognizance of the limitations of BMI, a study of the associations between adult food insecurity and percent body fat and changes in body weight was warranted. Hitherto, literature search had not shown any study on the associations between food insecurity and percent body fat among adults.

The persistence of food insecurity among a sector of the U.S. population (Nord, 2002) and the availability of nationally representative data gathered over the years, provide a better opportunity for the study of the associations between food insecurity and long-term nutritional indices, such as height. Even though adult height is largely determined by genetic potential, it is heavily modulated by childhood and adolescent living conditions including nutrition, socio-economic environment, disease and psychosocial stress (Cavelaars and others, 2000; Martorell and others, 1988). Height has therefore been used as a proxy for socio-economic and nutritional status, and a measurable long-term indicator of food insecurity (Scrimshaw, 2003; Cavelaars and others, 2000; Jelliffe and others, 1989). Short adult height is associated with several disease risks including coronary heart disease and stroke mortality, and prostate cancer (Wright and others, 2007; Silventoinen and others, 2003; Goldbourt and Tanne, 2002).

The purpose of this dissertation is to provide a better understanding of the health and nutritional status of vulnerable populations, especially food insecure persons, in the United States.

This dissertation is organized into seven chapters. Chapter 1 is the general introduction. Chapter 2 presents a review of the literature. Chapter 3 is a manuscript on the associations between adult food insecurity and body mass index, percent body fat and height. Chapter 4 is a manuscript on the associations between adult food insecurity and body weight change during one and ten years using multiple specifications. Chapter 5 is a manuscript on the associations between adult food insecurity and dyslipidemia and elevated plasma glucose. Chapter 6 is the general conclusions for the three studies. This is followed by the list of references and appendices.

CHAPTER 2

LITERATURE REVIEW

Definitions of Food Security and Food Insecurity

The consensus conceptual definitions of food security and food insecurity relevant to the United States of America came from the Life Sciences Research Office (LSRO) of the Federation of American Societies for Experimental Biology (FASEB) in 1990 (LSRO, 1990), which defined food security and food insecurity of a household as follows (LSRO Expert Panel, 1989):

> *Food security:* "access 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 assured ability to acquire acceptable foods in socially acceptable ways".
>
> *Food insecurity:* "limited or uncertain availability of nutritionally adequate and safe foods or limited or uncertain ability to acquire acceptable foods in socially acceptable ways".

The definition of food security implies that persons who resort to the use of emergency food assistance, scavenging and other coping strategies are food insecure (National Research Council, 2006; USDA, 2007). Issues of uncertainty, insufficiency and social unacceptability are also captured in the definition of food insecurity.

The above definitions were the products of discussions of an Expert Panel convened in 1989 and charged with identifying core indicators of nutritional state for difficult-to-sample populations (Anderson, 1990) for the American Institute of Nutrition, under the provisions of a cooperative agreement with the United States Department of Health and Human Services (DHHS) (National Research Council, 2006). These definitions that pertain to the United States are different from the international definition of food security. Internationally, food security is defined as a state in which "all people, at all times, have physical and economic access to sufficient, safe and nutritious foods to meet their dietary needs and food preferences for an active and healthy life" (USAID, 1992; World Food Summit, 1996).

Purpose of Measuring Food Insecurity in the United States

The primary purpose of the food security measurement is to estimate its prevalence in the United States (National Research Council, 2006; USDA, 2007). In addition, it helps to monitor changes in its prevalence over time both at the national and state levels to assess program policies and the possible need for program development (USDA, 2007). It provides a timely surveillance of the food security situation in the United States. Food security measurement could provide an understanding of the processes that cause food insecurity. It is important to understand the extent to which food insecurity is caused by a decline in household resources available for food acquisition. Food security measurement helps to further understand the effects of food insecurity, such as the precise mechanism through which food insecurity is reflected in dietary intake and subsequently on health. It also provides a platform for monitoring the adequacy of social safety nets such as food assistance programs, or the potential effect of a policy change (National Research Council, 2006; USDA, 2000; Carlson and others, 1999).

Currently, food security measurement in the United States is done at the household level by the National Center for Health Statistics (NCHS) during the National Health and Nutrition Examination Survey (NHANES) (USDA, 2007). The rationale for measuring food insecurity at the household level is to reports the number of people in food insecure households. When the household contains one or more food insecure persons, the household is considered food insecure. In addition, food is only one of the necessities that household members must have but households usually trade-off among needs to ensure long-term sustenance (USDA, 2006). For instance, households manage their wealth to ease difficulties, meet basic needs and contingencies, offset risk and decrease economic shock (USDA, 2006). Thus, one premise is that the household as a unit may provide a better picture of the food security situation than at the individual level. Nevertheless, individual level food security data are collected during the NHANES because the influences of food insecurity could vary across household members (Kaiser and others, 2002; Dixon and others, 2001; Hamilton and others, 1997). For instance adults shield children from the adverse effects of food insecurity by first adopting coping behaviors including limiting the quantity and quality of food consumed or skipping meals (Kaiser and others, 2002).

Overview of Food Insecurity Measurement in the United States

Prevalence of hunger and malnutrition in the United States in the 1960s came to light following a visit to the Mississippi Delta by the Senate Subcommittee on Employment, Manpower and Poverty, and a Southern Christian Leadership Conference report (Eisinger, 1998). Public attention was drawn to hunger and malnutrition which led to increases in programs and projects to ameliorate their effects. In 1968, Citizens Board of Inquiry into Hunger and Malnutrition in the United States, Field Foundation, found hunger and malnutrition to be widespread. Researchers in the private sector and government agencies increased their efforts to develop survey instruments to measure the severity and extent of hunger in the United States. The Food Research and Action Center sponsored a major series of surveys, including the Community Childhood Hunger Identification Project (CCHIP) in 1983-85, to study hunger among children (Hamilton and others, 1997). The CCHIP project developed an 8-item child food security scale for measuring food insecurity in children under the age of 12 years, which later became part of the U.S. food security measure (Radimer, 2002; Kleinman and others, 1998).

In the mid 1980s, the U.S Department of Agriculture (USDA) began to analyze information obtained from a single survey question on the adequacy of household food supply in the 1977-78 Nationwide Food Consumption Survey (Briefel and Woteki, 1992; Hamilton and others, 1997): "Which one of the following statements best describes the food eaten in your household?: 1) enough of the kinds of food we want to eat, 2) enough but not always the kinds of food we want to eat, 3) sometimes not enough to eat, 4) often not enough to eat". A food sufficiency question similar to the one in the nationwide food consumption survey was added in 1988, along with other questions on regular access to food supply adapted from the CCHIP measure. This food sufficiency question was included by the National Center for Health Statistics (NCHS) in the third National Health and Nutrition Examination Survey (NHANES III) as follows (Briefel and Woteki, 1992; Hamilton and others, 1997): “Which one of the following statements best describes the food eaten by you/your family?; 1) do you have enough food to eat, 2) sometimes not enough to eat, 3) or often not enough to eat?”. Those were significant efforts towards food insecurity measurement in the United States.

Congress enacted a National Nutrition Monitoring and Related Research Act (Public Law 101-445) in 1990. Section 103 of this act empowered the secretaries of the USDA and the DHHS to prepare and implement a ten-year comprehensive plan to assess the dietary and nutritional status of the U.S. population, specifically to recommend a standardized mechanism and instruments for defining and obtaining data on the prevalence of “food insecurity” or “food insufficiency” in the United States and methodologies that can be used at State and local levels (Carlson and others, 1999; Federal Register, 1993). Subsequently, a National Nutrition Monitoring Advisory Council was established in 1991 to provide scientific and technical advice on the development and implementation of a coordinated National Nutrition Monitoring and Related Research Program (NNMRRP). The USDA and DHHS in 1992 brought together representatives from several federal agencies, academic researchers, private organizations, and other stakeholders to form the Federal Food Security Measurement Project. This interagency group, after many deliberations, developed the food security instrument for assessing the food security status of U.S. households (National Research Council, 2006). The food security instrument developed by the interagency group, however, required further clarification on the measuring dimensions, consistency of terminology and standardization. Subsequently, the USDA and DHHS sponsored the first national conference on food security measurement and research in 1994, which brought together a large group of experts from government and academia, with the objectives that the food security and hunger measuring instrument was made straightforward and relevant to public policy and policy makers, and which reflected the variation in the level of severity of observed food insecurity (USDA and DHHS, 1994).

In 1994, the USDA and the Census Bureau agreed to develop, test, analyze and refine the food security questionnaire as a supplement to the 1995 Current Population Survey (CPS). A draft version of the food security questionnaire was revised, by an expert team from the Center for Survey Methods Research and the Current Population Survey Branch of the Census Bureau, after deliberations and extensive cognitive testing and reviews (Hamilton and others, 1997). Following a field test in April 1994, further revisions were made to the food security instrument and was administered as a supplement; Food Security Supplement (FSS), to the CPS in April 1995 (USDA and DHHS, 1994; Singer and Hess 1994; Andrews and others, 1998). In 1995 and subsequent years, a set of 70 questions comprising the FSS has been administered with the Census Bureau's CPS (Carlson and others, 1999; Hamilton and others, 1997).

The Food Security Survey Module and Applications

Among the 70 questions comprising the FSS is a set of 18 questions that form the Household Food Security Survey Module (FSSM) used to assess the prevalence of food insecurity in the United States (Alaimo and Froelich, 2004; USDA, 2000; Carlson and others, 1999). The 18 questions were chosen to meet certain statistical assumptions, which were: 1) the measure from the FSSM should be expressed as a scale in a single dimension, 2) the scale should be composed of multiple items that range in severity, 3) severity should be primarily captured across items, not within items, 4) the items should have a Guttman property (i.e., affirmation of a more severe item should mean that all less severe items were also affirmed), 5) an indicator should be created by choosing reference cut-offs along the scale (Alaimo and Froelich, 2004).

The 18 questions of the FSSM comprise 16 questions and 2 follow-up questions and have been called the food security core module (USDA, 2000) (Appendix 1: FSSM). Among these, a set of 10 questions are administered for households with no children to assess adult food insecurity and a set of 8 questions are administered for assessment of child food insecurity (USDA, 2007; Alaimo and Froelich, 2004). The full set of 18 questions in the FSSM has been published elsewhere (Nord and others, 2005; USDA, 2000; Carlson and others, 1999). In order to decrease respondent burden, there is one optional screener question with two follow-up questions, which are not part of the FSSM but help to screen out food secure households who are above 185 percent of the Federal poverty line and give no indication of food-access problems (USDA, 2007).

The questions in the FSSM elicit information on whether the household experienced food-related difficulties due to lack of resources with a reference period of

12 months. The severity of the food-related difficulties captured by the FSSM range from “worrying about running out of food” to “children not eating for a whole day” (National Research Council, 2006; Nord and others 2007). The FSSM questions ask respondents to report only experiences, perceptions or behaviors resulting from inadequate financial resources so that voluntary causes of hunger or meals skipped due to dieting, illness and busy schedules are not captured (Carlson and others, 1999). The FSSM assesses social, economic and other resource constraints related to meeting basic food needs because they were deemed to be more policy relevant than assessment of physical access or disability (National Research Council, 2006). Measurement of food insecurity at the household or individual level in the U.S. involves the measurement of quantitative, qualitative, psychological and social or normative factors that are central to the experience of food insecurity, qualified by their involuntary and cyclical nature. Results of several studies that tested the validity of the FSSM suggest that it is valid for measuring food security status of U.S. households, adults and children (Kendall and others, 1996; Frongillo and others 1997b; Frongillo, 1999).

For surveys that need to cut down the number of questions, a standard 6-item subset of the 18-item FSSM has been developed which approximates closely the three main categories of food security status: food secure, food insecure without hunger, and food insecure with hunger. When compared with the 18-item FSSM, the 6-item measure was shown to classify about 98% of households correctly (Blumberg and others, 1999). The weaknesses of the 6-item measure, in comparison to the full measure, are that there is slight loss in sensitivity or specificity, and it does not capture the more severe range of food insecurity where children's hunger and more severe adult hunger occur (USDA, 2000; Hofferth and Reid, 1998).

Two scales are assigned to the FSSM, a categorical measure and a continuous scale, both of which are linked to a status-level classification (Appendix 2). The use of one depends on the objective of the food insecurity assessment but both are useful complementary tools (Carlson and others, 1999). The continuous scale is suitable for research models that require estimation of regression and correlation values because it includes the maximum information that can be supported by the core module data (USDA, 2000). For comparing prevalence of food insecurity and hunger across subpopulations or regions, the categorical measure is most appropriate. It is often the preferred tool for preliminary or exploratory research into the kind, causes, and consequences of food insecurity, and the convenient form for reporting food security monitoring data (USDA, 2000; Carlson and others, 1999). In addition, the categorical measure is more appealing to advocacy groups and politicians. The category boundaries or scale-score reference cut-offs of the categorical measure vividly define ranges of severity that are pertinent to policy discussion and which reflect any clear conceptual distinctions between the several broad stages of severity in food insecurity (USDA, 2000; Carlson and others, 1999). The FSSM exhibits Guttman property: a progressive or accretional scale that shows that a person who reports a more severe item also reports all the less severe items (Habicht and others, 2004; Carlson and others, 1999). The FSSM scores are graded according to how many of the 18 items are answered affirmatively, augmented by the Guttman property of the scale which substantiates this scoring method (Habicht and others, 2004). The higher the score, the more severe is the food insecurity, implying a form of Rasch modeling.

Households are classified into food security categories using Rasch modeling (Alaimo and Froelich, 2004). Rasch modeling is a one parameter logistic model which assumes that households responses to food insecurity questions are determined by a continuous latent variable and not by the severity of the question (Alaimo and Froelich, 2004). Households with the same total score on the survey (i.e., affirmed the same number of questions) are estimated to have the same level of food insecurity. This implies that Rasch modeling does not account for differences among the particular response patterns, or which questions each household affirmed, but instead utilizes the total number of items answered affirmatively to estimate food insecurity prevalence (Alaimo and Froelich, 2004).

The Household Food Security Category Labels and Revisions

The FSSM has remained essentially unchanged over the years (Alaimo and Froelich, 2004). The part of the FSSM administered to a household depends on whether there are children in the household or not, which also determines which items are used to categorize households (Nord and others, 2005). At the onset of food security measurement in the United States in 1995, households which comprised of only adults were categorized into 4 status-levels (or food security categories) using the 10 adult questions (USDA, 2000; Carlson and others, 1999):

1. *Food secure* - if household denied all items or affirmed only 1-2 items.
2. *Food insecure without hunger* - if household affirmed 3-5 items.

3. *Food insecure with hunger moderate* - if household affirmed 6-8 items.

4. *Food insecure with hunger severe* - if household affirmed 9-10 items

If household includes children, the 8 child items are included to categorize households into 4 status-levels (USDA, 2000; Carlson and others, 1999):

1. *Food secure* - if households denied all items or affirmed 1-2 items.

2. *Food insecure without hunger* - if households affirmed 3-7 items.

3. *Food insecure with hunger moderate* - if household affirmed 8-12 items.

4. *Food insecure with hunger severe* - if household affirmed 13-18 items.

The above status-levels were the ones introduced with the 1998 CPS food security data release (Carlson and others, 1999). However, the 1999-2000 and 2001-2002 household food security data were released with the labels slightly modified to include "*fully food secure"* and "*marginal food security"* (USDA, 2000; Hanson and others, 2007). For instance, the adult labels now became:

1. *Fully food secure* - if household denied all items or affirmed 0 items.

2. *Marginal food security* - if household affirmed 1-2 items.

3. *Food insecure without hunger* - if household affirmed 3-5 items.

4. *Food insecure with hunger* - if household affirmed 6-10 items.

At the recommendation of the Committee on National Statistics (National Research Council, 2006), another revision of the food security category labels was made and released with the 2006 food security survey reports (USDA, 2007; National Research Council, 2006). The revision was made with no changes in the food security scale-score reference cut-offs. In that revision, households that were food insecure without hunger were classified as *low food security* and households that were food insecure with hunger were classified as *very low food security*. The reason for the revision was to distinguish the physiological state of hunger from indicators of food availability (USDA, 2007). Thus the food security category labels with scale score cut-points, as at March 2008 for instance, were (USDA, 2007):

1. *Food secure* - if household denied all items or affirmed 0 items.
2. *Marginal food security* - if household affirmed 1-2 items.
3. *Low food security* - if household affirmed 3-5 items.
4. *Very low food security* - if household affirmed 6-10 items.

Food Insecurity Prevalence and Determinants in the United States

Results from the household food security surveys from 1995 to 2006 using the FSSM indicate that about 9.0-11.9% of households in the United States could be categorized as food insecure (USDA, 2007). In 1995, 11.9 million households out of the estimated 100.2 million households were food insecure, affecting about 35 million people (Carlson and others, 1999). In 2006 the number of food insecure households in the United States was 12.6 million, which accounted for 10.9% of households in the United States, comprising an estimated 35.5 million people (USDA, 2007; Carlson and others, 1999). This prevalence of food insecurity is alarming because the adverse effects of food insecurity encompass all aspects of social and economic life.

Several factors contribute to the prevalence of food insecurity in the United States (Figure 1). These factors vary substantially from state to state (USDA, 2006). Even though lack of economic resources is a common determinant of food insecurity, other factors such as lack of physical access or disability may be more important in certain sub-populations such as elderly persons (Carlson and others, 2006). Generally, food insecure persons tend to have the following characteristics: 1) income is less than 185 percent of the Federal poverty threshold, 2) has less than high school education, 3) of minority status, 4) lives in a rented home, 5) lives in the central city of a metropolitan area, 6) lives in a household in which no adult is employed, 7) lives in the southern or western United States, 8) is a single parent with children, 9) has three or more children, 10) is disabled, 11) is a non-citizen, (Nord, 2007b; USDA, 2006; Carlson and others, 1999). At the state level: a) low wages, b) high rental cost of housing, c) low participation in food assistance programs and, d) high unemployment rates have been cited as influential factors of food insecurity (Nord, 2007b; USDA, 2006).

Most often, food insecurity is set within a causal phenomenon which begins with economic constraints and ends with nutritional shortcomings (Rose, 1999). Income is an important determinant of food security status. Food security status improves as income rises. However, not all individuals from high income household are food secure. For instance, results from the 1995 CPS indicated that 17% of households with incomes <50% and 1.4% of households with incomes >185% of the poverty threshold were food insecure with hunger (Rose, 1999; Hamilton and others, 1997). Similarly results from the 1989-1991 Continuing Survey of Food Intake by Individuals (CSFII) showed that 16% of households with incomes <50% of the poverty threshold were food insecure with hunger which declined to 1% for households with incomes >185% of the poverty threshold (Rose and others, 1998). Examining the NHANES 1988-1994 data sets,

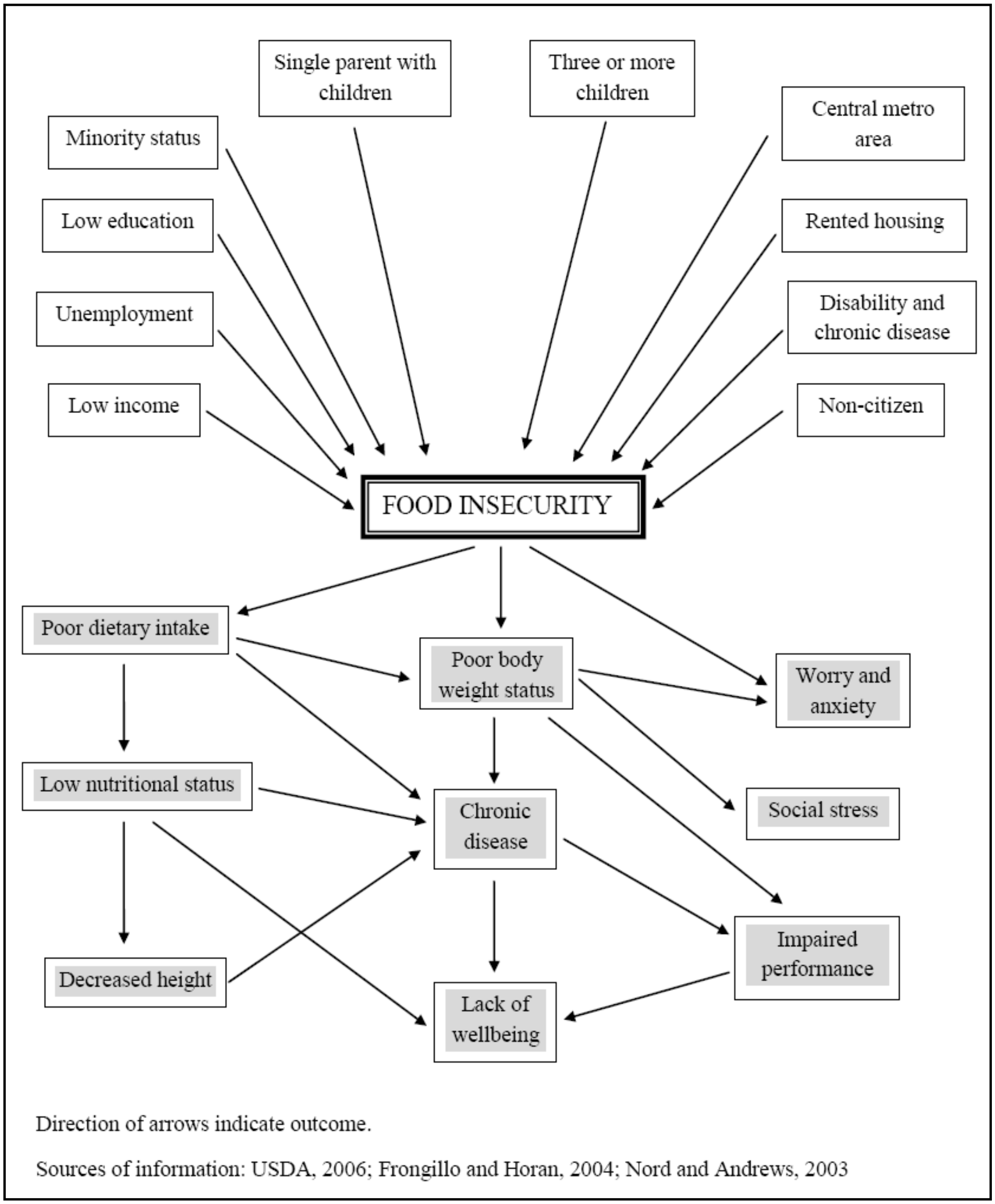

Figure 1. A Schematic of some determinants and consequences of food insecurity in the United States

Alaimo and others (1998) observed that 15% of children from low-income families and 2% of children from middle-income families were food insecure. A community health survey of income-related household food security in 2004, indicated that food insecurity was highest for those with incomes in the lowest (48.3%) and lower-middle (29.1%) categories of household income adequacy, compared with those in the middle (13.6%), upper middle (5.2%) and highest (1.3%) categories of household income adequacy (Health Canada, 2007).

Food Insecurity and Obesity

The attention of the nutrition community was drawn to the food insecurity-OB relationship when Dietz (1995) published a case study of a 7-year-old food insecure obese girl who experienced food shortages at regular intervals in each month before her mother received the welfare check. In that report, Dietz (1995) stated that it was either food choices or physiological adaptation in response to episodic food shortages that had resulted in increased body fat (Dietz, 1995). Other researchers have accorded the reasons given by Dietz (Drewnowski and Specter, 2004; Kaiser and others, 2002; Tarasuk, 2001; Olson, 1999). The association between food insecurity and OB continues to be observed (Hampton, 2007; Wilde and Peterman, 2006; Adams and others, 2003; Townsend and others, 2001). Intermediate levels of food insecurity dominate in the positive relationship between food insecurity and OB (Adams and others, 2003; Dietz, 1995).

The positive food insecurity-OB association among women has been qualified as an apparent paradox (Hampton, 2007) and a seemingly contradictory relationship

(Wilde and others, 2006). Among men, whereas some studies have found associations between food insecurity and obesity (Hanson and others, 2007; Wilde and Peterman, 2006) others have found the reverse (Gulliford and others, 2003; Vozoris and Tarasuk, 2003; Sarlio-Lahteenkorva and Lahelma, 2001). Most reports indicate positive relationships between food insecurity and obesity in women and non-Hispanic White adolescents and a negative relationship in the elderly and younger children. It is likely that a positive association between food insecurity and OB is observed depending on the sample, control variables and severity of food insecurity examined. Nevertheless, one expects the food insecurity-obesity relationship to vary by the level and severity of food insecurity (Vozoris and Tarasuk, 2003; Olson, 1999; Frongillo and others, 1997).

Several national studies indicate a strong association between food insecurity and OB. In a study involving women of childbearing age, Olson (1999) observed a significantly positive association between BMI and food insecurity after controlling for income and other important confounders. She observed a 37% prevalence of obesity among food insecure compared to 26% among food secure households. Townsend and others (2001) used data from the 1994-1996 Continuing Survey of Food Intakes by Individuals (CSFII) to examine the relationship between food insecurity and overweight among women. They observed that food insecure women were more likely to be overweight and that the prevalence of overweight among women increased as food insecurity intensified from food secure (34%), mild food insecurity (41%) to moderate food insecurity (52%) (Townsend and others, 2001). Using the National Health and Nutrition Examination Survey 1988-1994 (NHANES III) to study the associations of food insecurity and overweight among 19-55 year old women, Basiotis and Lino (2003) found a higher percentage of overweight among food insecure women, 58%, than their food secure counterparts, 47%. A national survey of 16-year old students, to study whether food insecurity was associated with weight control behavior, found that those who were food insecure were the ones trying to gain weight (Gulliford and others, 2005; Gulliford and others, 2006a).

Evidence of the food insecurity-obesity relationship is also provided by local, county and state level studies. Adams and others (2003) studied data from the 1998 and 1999 California Women's Health Survey to examine patterns of food insecurity and obesity in women. Their results showed that obesity was more prevalent in food insecure (31.0%) than in food secure (16.2%) women (Adams and others, 2003). Food insecurity without hunger was associated with increased risk of obesity in Whites (OR, 1.36) and other races (OR, 1.47) (Adams and others, 2003). In addition, the more severe form of food insecurity, food insecurity with hunger, was associated with increased risk of obesity in Asians, Blacks and Hispanics (OR, 2.81) but not for non-Hispanic Whites (OR, 0.82) (Adams and others, 2003). Laraia and others (2004), in a study of the associations between concern about enough food and obesity in an adult population in Louisiana and New York, observed a positive food insecurity-obesity relationship which vanished after controlling for income.

A study of rural households in Malaysia indicated that food insecurity was significantly associated with obesity and abdominal fatness (Shariff and Khor, 2005). In a national sample of Canadians, Vozoris and Tarasuk (2003) examined the association between food insufficiency and physical, mental and social health. They observed that men from food insufficient households were significantly less likely to be overweight

(Vozoris and Tarasuk, 2003). In that study, even though women from food insufficient households were more likely to be obese, the association vanished after controlling for income and other important covariates (Vozoris and Tarasuk, 2003).

Why food insecurity may associate with obesity

The mechanisms responsible for the positive association between food insecurity and OB have not been established but several plausible explanations have been offered, including lack of access to resources (Kaiser and others, 2002; Tarasuk, 2001; Olson, 1999), preference for calorie-dense foods (Drewnowski and Specter, 2004; Gulliford and others, 2003; Tarasuk, 2001), adaptation to cyclic or episodic food availability (Gulliford and others, 2006a; Wilde and Peterman, 2006; Cook and others, 2004) and probably undernutrition during childhood and adolescence (Martins, 2004).

Food insecurity, calorie-dense diets and obesity

Among the reasons forwarded to explain the food insecurity and OB relationship is that food insecure persons may have preference for calorie-dense foods. It is speculated that food insecurity may engender weight gain by encouraging food insufficiency coping behavior and disordered eating pattern (Kaiser and others, 2002; Sarlio-Lahteenkorva and Lahelma, 2001; Townsend and others, 2001). Food insecure persons may have a preference for low-cost energy-dense foods (Drewnowski and Specter, 2004; Gulliford and others, 2003; Tarasuk, 2001) such as high-fat and high-sugar processed foods which taste palatable but are often less expensive than fresh fruits, vegetables and low-fat dairy products (Hampton, 2007; Drewnowski and Specter, 2004). This coping strategy may lead to energy overconsumption because fat is not very satiating (Rolls, 2000).

Food insecurity, lack of access to resources, socio-economic deprivation and obesity

The positive association between food insecurity and OB among women may be the result of socio-economic deprivation and lack of access to resources (Kaiser and others, 2002; Tarasuk, 2001; Olson, 1999; Dietz, 1995). The relationship between food insecurity and weight status in low-income Latino women was examined by Kaiser and others (2004). Their results showed that food insecurity with hunger was significantly related to obesity, and severe past food insecurity was related to obesity in the U.S.-born Latino women. In a study to examine the associations between past and present economic disadvantage and food insecurity, and body size in a nationally representative sample of Finish men and women, Sarlio-Lahteenkorva and Lahelma (2001) found that thin people were more likely to report hunger and to show most food insecurity. However, obese people reported buying cheaper food due to economic problems and fear of running out of money for food than did normal weight subjects (Lahteenkorva and Lahelma, 2001). In a study to investigate associations between family income, food insufficiency, and being overweight in US children, Alaimo and others (2001b) observed that younger food insufficient girls were less likely to be overweight, whereas non-Hispanic White older food insufficient girls were more likely to be overweight than food-sufficient girls.

Food insecurity, cyclic food availability and obesity

Among the food insecure, the boom and bust cycles of food availability may encourage over-eating when food is available (Gulliford and others, 2006a; Cook and others, 2004; Lahteenkorva and Lahelma, 2001). Food insecurity associates with food insufficiency coping behaviors including disordered eating pattern and meals skipping (Kaiser and others, 2002; Sarlio-Lahteenkorva and Lahelma , 2001; Townsend and others, 2001). Both voluntary and involuntary food deprivation result in a variety of cognitive and behavioral changes including preoccupation with food and eating (Polivy, 1996; Radimer and others, 1992). In addition, cyclical food availability among food insecure persons may result in metabolic changes which result in more efficient utilization of food energy (Gulliford and others, 2006a).

Wilde and Ranney (1998) observed that food intake was characterized by a sharp peak in the three days after receipt of food stamp benefits but declined towards the end of the month when food stamp benefits were depleted and that the cyclical food availability could result in weight gain. Jones and others (2003) compared the risk of being overweight in children ages 5-12 years between food insecure and food secure low-income households in relation to food stamp program and the national school lunch and breakfast programs participation using the 1997 Panel Study of Income Dynamics. They observed that food insecure girls who participated in all 3 programs had a 68% reduced odds of being at risk of overweight when compared with food insecure girls in nonparticipating households (Jones and others, 2003). Their results further showed that girls in food secure households generally had no greater or less risk of overweight if they participated in any or all of the programs, and boys in both food insecure and food secure households had no greater or less risk of overweight if they participated in any or all of the programs (Jones and others, 2003).

Undernutrition in childhood has been associated with higher percentage of body fat in adults (Martins and others, 2004). Among the under-nourished, metabolic changes may occur which may result in more efficient utilization of food energy or conservation of fat (Martins and others, 2004; Benefice and others, 2001; Dulloo and Girardier, 1993).

Food Insecurity and Chronic Disease

The potential adverse health outcomes of food insecurity are many (Figure 1). Impaired performance and chronic disease are common outcomes of food insecurity (USDA, 2007). Anxiety and worry usually result from uncertainty about food availability (Frongillo and Horan, 2004). Alienation, deprivation, distress, adverse changes in family and social interactions and lack of wellbeing are commonly experienced by food insecure persons (Frongillo and Horan, 2004; Nord and Andrews, 2003; Hamelin and others, 1999). Food insecurity associates with chronic diseases such as CVD, type 2 diabetes and hypertension, as well as psycho-social distress, food allergy and OB.

Studies show strong associations between food insecurity and chronic disease, and poor health. Lee and Frongillo (2001) examined the association between food insecurity and health status of an elderly sample in the U.S. using data from the NHANES III (1988-1994) and the Nutrition Survey of the Elderly in New York State, 1994. Food insecure elderly persons were more likely to have lower skinfold thickness, poor self-reported health and higher nutritional risk (Lee and Frongillo, 2001). In a study among adults, poor self-rated health and physical limitations, poor functional health status, and depression were associated with food insecurity (Holben, 2004). Sharkey (2003) examined the associations between food sufficiency status and nutrition, and health outcomes among 279 older women receiving regular home-delivered meal service in North Carolina at Chapel Hill. He observed that, independent of income and other variables, food insecure women were more likely to report depression, CHD, high blood pressure and diabetes, musculoskeletal problems and burden of multiple diseases (Sharkey, 2003). Stuff and others (2004) examine the association between household food insecurity and self-reported health status among adults in 1,488 households in the Lower Mississippi Delta region. They observed that adults in food-insecure households were significantly more likely to rate their health as poor or fair and had significantly lower physical and mental health scores (Stuff and others, 2004).

Vozoris and Tarasuk (2003) examined the relationship between food insufficiency and physical, mental and social health in a national sample of Canadians. They observed that persons from food insufficient households were more likely to report poor or fair health, to have poor functional health, restricted activity and multiple chronic conditions, major depression and distress, and to report CHD, type 2 diabetes, high blood pressure and food allergies (Vozoris and Tarasuk, 2003). Similar to the results of Vozoris and Tarasuk (2003), other studies have found food insecurity to be associated with maternal depressive symptoms (Whitaker and others, 2006; Wu and Schimmele, 2006). A greater risk of type 2 diabetes has been observed among food insecure adults (Hampton, 2007; Seligman and others, 2007), making it difficult for them to adhere to dietary modifications associated with type 2 diabetes (Hampton, 2007).

One possible explanation for the associations between food insecurity and chronic disease draws on Barker's hypothesis that many human fetuses adapt to a limited supply of nutrients and in doing so permanently change their physiology and metabolism and that these programmed changes may be the origins of a number of diseases in later life (Barker, 1997). Thus the quality of fetal growth and development could have major consequences for susceptibility to disease in adult life. It is possible that food insecure persons may be susceptible to chronic disease due to limited supply of nutrients *in utero*. The number of adult diseases that may originate from environmental influences during fetal growth and development includes cardiovascular disease, hypertension, stroke, type 2 diabetes and depression (Ozanne and others, 2004; Barker, 1997) which already have strong linkages with food insecurity (Hampton, 2007; Seligman and others, 2007; Sharkey, 2003; Vozoris and Tarasuk, 2003).

Food insecurity and cardiovascular disease

Studies on the associations between food insecurity and dyslipidemia and elevated plasma glucose (EPG) and hence CVD are scarce. The few studies that reported on the associations between food insecurity and CVD (Sharkey, 2003; Vozoris and Tarasuk, 2003) were based on self-rated disease conditions but not on objective assessments (Seligman and others, 2007; Dixon and others, 2001).

Evidence for significant associations between food insecurity and risks of chronic disease, including cardiovascular disease (CVD) have been reported (Holben, 2004; Vozoris and Tarasuk, 2003; Dixon and others, 2001). Population-based prospective studies indicate that dyslipidemia, indicated by high levels of serum triglyceride (TG), total cholesterol (TC), low-density lipoprotein-cholesterol (LDL-C) and high-density lipoprotein cholesterol (HDL-C) pose significant risk for CVD (Edelstein and others, 2005; Patt and others, 2003; Aronne, 2002; Denke, 1993).

Intermediate-level food insecurity associates with OB (Wilde and Peterman, 2006; Adams and others, 2003; Townsend and others, 2001; Dietz, 1995), which are independent risk factors for CVD partly through their associations with elevated levels of TC, LDL-C and hyperglycemia, and depressed levels of HDL-C (NCEP, 2007; Edelstein and others, 2005; Gensini and others, 1998). It has been observed that the greater the weight gain since age 18 years, the greater the risk associated with type 2 diabetes, CVD and obesity-related mortality (Aronne, 2002; Bray, 1998; Willet and others, 1995). Weight gain of about 10kg in women after 18 years doubles the risk for CVD (Aronne, 2002).

In a 20-year follow-up study of body weight change and health outcomes in middle-aged men in the U.S., Kaleta and colleagues (2005) found that, CVD risk was 4 times higher and ischemic heart disease (IHD) 3 times higher for men who gained more than 5 kg compared with men who had stable weight. Sullivan and others (2004) evaluated the prognostic significance of weight change and mortality in a group of elderly patients and observed that weight gain of 3 kg or more per year was associated with 3.7 time risk of mortality compared with the stable weight (± 1 kg per year) group. Jenkins (2004) in a study of body weight change as a potential risk factor for the onset of functional impairment in young-old adults, observed that weight gain was associated with greater risk of lower body mobility impairment. In a 5-year follow-up study of the effect of long-term BMI changes on the subsequent incidence of hypertension in a large sample of community-residing Japanese men and women, Lee and others (2004) found that those who developed hypertension had significantly higher baseline BMI than those who did not.

Food insecurity may associate with CVD through its associations with poor diet. Food insecurity associates with poor dietary intake (Gulliford, 2005; Sharkey, 2003; Dixon, 2001, Rose, 2000) which influences levels of serum lipoproteins (Greene and others, 2006; Gardner and others, 2005, Stefanick and others, 1998). Among the food insecure, there may be decreases in the intakes of antioxidant nutrients which are protective against CVD (Kirkpatrick and Tarasuk, 2008; Hromi-Fiedler and others, 2007; Lee and Frongillo, 2001). In a national study of the differences in dietary intakes and serum nutrients between adults from food-insecure and food-secure families, Dixon and others (2001) observed that adults from food insecure families had lower serum concentrations of provitamin A carotenoids and vitamin E which are protective against CVD (Dixon and others, 2001). In Connecticut, Hromi-Fiedler and others (2007) observed that pregnant women who were food insecure with hunger were significantly less likely to consume adequate amount of provitamin A caroteniods and selenium, which are protective against CVD, than those who were food secure (Hromi-Fiedler and others, 2007).

Food insecurity, dyslipidemia and elevated plasma glucose

Literature search indicated only one study on the associations between food insecurity and dyslipidemia (Dixon and others, 2001). Dixon and others (2001) used the NHANES III data set to study, among other components, differences in the concentrations of serum TC, LDL-C and HDL-C among adults from food-insecure and food-secure families. Their results showed that younger adults and older adults from food insecure families associated with lower concentrations of TC and lower concentration of HDL-C, respectively (Dixon and others, 2001). In their study, the National Cholesterol Education Program (NCEP) reference guidelines were used to determine cut-points for serum lipids (Dixon and others, 2001).

Dyslipidemia has generally been assessed using multiple indicators including serum concentrations of total TG, TC, LDL-C, HDL-C and their ratios (Edelstein and others, 2005). Appropriate reference clinical guidelines/cut-offs have been established for the identification of dyslipidemia and EPG (NCEP, 2007; AHA, 2004; Brown, 2000; ADA, 1997) as follows:- total cholesterol (TC): normal, TC <240 mg/dl and high, TC ≥ 240 mg/dl (NCEP, 2007; Brown, 2000), LDL-C: normal, < 130 mg/dl; high, ≥ 130 mg/dl (NCEP Expert Panel, 2001), TG: normal, <150 mg/dl; high, ≥ 150 mg/dl (Kompoti and others, 2006; Patt and others, 2003), LDL-C/HDL-C ratio: normal, <2.5 and high, ≥ 2.5 (Herron and others, 2002; McNamara and Min, 2002), TC/HDL-C ratio: normal, <3.5; high, ≥ 3.5 (Lemieux and others, 2001; Anderson and others, 1991), TG/HDL-C ratio: normal, <3.0 and high, ≥ 3.0 (McLaughlin and others, 2003). HDL-C: men - normal, ≥ 40; low, < 40 mg/dl, and women - normal, ≥ 50; low, <50 mg/dl (Kompoti and others, 2006; Patt and others, 2003), Literature search did not show any study on the associations between food insecurity and elevated plasma glucose (EPG). Elevated plasma glucose assessment is used to identify pre-diabetic or persons at risk of type 2 diabetes (Edelstein and others, 2005). Elevated fasting plasma glucose reference clinical guidelines were based on the American Diabetes Association criteria: normal, < 95; EPG, ≥ 95mg/dl (Edelstein and others, 2005; ADA, 1997).

Food Insecurity and Body Weight Measures

In addition to the use of BMI guidelines, the food insecurity-overweight/obesity relationship has also been studied using other indices of body weight status, including absolute BMI change over time (Aronne, 2002; Bray, 1998; Willet and others, 1995), absolute weight change over time (Wilde and Peterman, 2006; Kaleta and others, 2005) and percentage body weight change (Wannamethee and others, 2001).

Wilde and Peterman, (2006) used a multivariate approach to examine the relation between household food security status and current measured body weight and body weight change using the NHANES 1999-2002 datasets. They observed that, compared with women in households that were fully food secure, women in households that were marginally food secure or food insecure without hunger were significantly more likely to be obese. Women in households that were marginally food secure were significantly more likely to gain at least 4.54 kg (Wilde and Peterman, 2006). Compared with men in households that were fully food secure, men in households that were marginally food secure were more likely to be obese and to gain at least 4.54 kg (Wilde and Peterman, 2006). Jones and Frongillo (2007) used data from the Panel Study of

Income Dynamics to study the relationship between food insecurity and subsequent weight gain in women. They observed an average weight gain of 1.1 kg over 2 years, and there were no differences in the percentage of women who gained a clinically significant weight (2.3 kg) between food security levels (Jones and Frongillo, 2007).

Hanson and others (2007) analyzed the associations between food insecurity and body weight, gender and marital status using the NHANES 1999-2002 and observed that marginal food security among both men and women associated with significant increase in BMI. In their study, when compared with never-married women, food insecure women who were married, living with partners, or widowed were more likely to be obese (Hanson and others, 2007).

When examining associations between food insecurity and body weight gain, only few studies controlled for smoking status (Armour, 2007). Many of the previous studies on the associations between food insecurity and weight change either did not control for smoking status (Hanson and others, 2007; Wilde and Peterman, 2006) or used lower weight change specifications (Jones and Frongillo, 2007) which were less applicable to the current rate of weight gain among U.S. adults. Smoking is common among food insecure persons and influences their dietary intake and composition (Troisi and others, 1991; Klesges and others, 1990) as well as body weight (Lissner and others, 1992; Manson, 1987). However, there is a significant inverse association between smoking and body weight (Manson, 1987).

Food insecurity and percent body fat measurements

To date, no study had examined the associations between food insecurity and body fat. However, an objective way of studying the food insecurity-obesity relationship is by examining body fat using bioelectrical impedance analysis (BIA). Bioelectrical impedance analysis is a relatively simple, quick and non-invasive way of measuring body composition, including body fat, total body water (TBW) and fat-free mass (FFM) (Kyle and others, 2004; Bolanowski and Nilsson, 2001; NIH, 1994). The BIA method is based on the conduction of electrical current in the body and differences in electrical conductivity between body fat and water combined with body weight and height dimensions (Bolanowski and Nilsson, 2001; NIH, 1994). In BIA, measurement of body fat relies on electrical impedance of body tissues, which provides an estimate of TBW (NIH, 1994). Fat-free mass and body fat are then calculated from the values of TBW using empirical BIA equations (Frisard and others, 2005; Kyle and others, 2001). Impedance measures vary with the frequency of the electrical current used, but typically 50 kHz is applied when a single frequency is used (Kyle and others, 2001; NIH, 1994). Prior to conducting BIA, subjects must meet the following conditions: 1) abstain from eating and drinking within 4 hours of the test, 2) avoid physical exercising within 12 hours of the test, 3) empty bladder completely prior to testing, 4) must not drink alcohol within 48 hours of the test, 5) must not have taken diuretics prior to testing (Kyle and others, 2004; NIH, 1994).

Many empirical BIA equations have been developed to estimate TBW and FFM as a function of impedance, age, gender, height and body weight (Kyle and others, 2001; Roubenoff and others, 1997; NIH, 1994). Most of these equations have been validated in healthy adults against several body composition techniques including Dual Energy X-ray Absorptiometry (DEXA), a reference method (Frisard and colleagues, 2005; Bolanowski and Nilsson, 2001; Kyle and others, 2001). One of the widely utilized BIA equations for estimation of percent body fat is the single body fat prediction equation developed by Kyle and colleagues (2001).

In a study to develop a single body fat prediction equation for adults ages 20-94 years, a very high correlation, r = 0.986, between body fat measures from BIA and DEXA was observed (Kyle and others, 2001). Bolanowski and Nilsson (2001) compared body composition measures obtained using BIA and DEXA and reported that there was a significant linear relationship between BIA and DEXA in terms of body fat mass, percent body fat and lean body mass. When Frisard and colleagues (2005) assessed the accuracy of body composition measurement using BIA, they concluded that BIA was an accurate method when compared with DEXA. However, due to differences in body dimensions, composition and sample origin, BIA is not suitable for the elderly and extremely obese persons (Kyle and others, 2004; NIH, 1994). It is also not suitable for individuals with abnormal hydration (Kyle and others, 2004).

Food Insecurity and Dietary Measures

A food insecure individual is characterized by limited or uncertain availability of nutritionally adequate and safe foods (Anderson, 1990; LSRO, 1989). It is thus not unexpected that research reports associate food insecure persons with poor diets which may compromise nutritional status and hence health.

Studies of nationally representative data show lower intakes of protein, many vitamins, minerals, and quantities of various food groups by members of food insecure households compared with their food secure counterparts (Rose, 1999; Rose and Oliveira 1997; Cristofar and Basiotis 1992). In a recent national study to examine the relationship between household food security status and adults' and children's dietary intakes and prevalence of nutrient inadequacies, Kirkpatrick and Tarasuk (2008) observed poorer dietary intakes among adolescents and adults in food-insecure households. In that study, higher estimated prevalence of nutrient inadequacies were apparent among adolescents and adults in food-insecure households, with the differences most marked for protein, vitamin A, thiamin, riboflavin, vitamin B_6, folate, vitamin B_{12}, magnesium, phosphorus and zinc (Kirkpatrick and Tarasuk, 2008). They observed that among children, few differences in dietary intakes were apparent and there was little indication of nutrient inadequacy (Kirkpatrick and Tarasuk, 2008). Kirkpatrick and Tarasuk (2008) reasoned that the observed differences between the results of the children and adults lie in the continuum of food insecurity whereby the quality and quantity of adults' intakes are typically affected before children's intakes are compromised (Kirkpatrick and Tarasuk, 2008) which supports the opinion of other researchers (Bickel and others, 2000; Radimer, 1992). Dixon and others (2001) examined the NHANES III data to study differences in dietary intakes and serum nutrients between adults from food-insecure and food-secure families. They observed that adults from food insecure families had lower intakes of calcium and vitamin E, and lower frequency of consumption of milk and milk products, fruits and fruit juices and vegetables compared with their food secure counterparts (Dixon and others, 2001). The study also showed that younger adults from food insecure families had lower serum concentrations of vitamin A and provitamin A carotenoids, but older adults had lower intakes of energy, vitamin B_6, magnesium, iron and zinc and lower serum concentrations of albumin, vitamin A, provitamin A carotenoids and vitamin E (Dixon and others, 2001). Lee and Frongillo (2001) and Rose and Oliveira (1997) had reported similar findings.

Studies at the state and county levels show similar findings as the national studies. Hromi-Fiedler and others (2007) studied food insecurity status and nutrient intakes among pregnant low-income Latino women in Connecticut. Pregnant women who were food insecure with hunger were significantly less likely to consume adequate amount of protein, vitamin B_{12}, zinc, retinol, vitamin D and selenium than those who were food secure **(**Hromi-Fiedler and others, 2007). In a study to document food insecurity experiences and coping strategies among adult urban soup kitchen consumers, Wicks and others (2006) observed that even though participants demonstrated adequate knowledge and desire to eat healthful foods, meals were missed and quantities restricted as a coping strategy for food insecurity (Wicks and others, 2006). Kendall and others (1996) in a study of the relationship between food insecurity and food consumption among women in a rural New York State county had reported similar findings as Wicks and others (2006).

In a study of food insecurity and dietary intake of immigrant food bank users in Canada, Rush and others (2007) observed that despite being highly educated, all respondents had experienced some form of food insecurity within the previous 30 days and the total daily energy intake was below recommendation whereas a large proportion of participants consumed diets low in fruits and vegetables, milk and dairy products (Rush and others, 2007). Assessing dietary intake in Trinidad and Tobago using the United States FSSM, Gulliford and others (2003) observed that food insecure persons were less likely to consume fruits or green vegetables or salads (Gulliford and others, 2003). This observation was similar to that of Radimer and others (1997) who observed lower intakes of fruits, vegetables and meat among food insecure men and women in an Australian sample (Radimer and others, 1997).

Food Insecurity and Adult Height

A literature search did not show documentation on long-term nutritional indicators that reflect earlier life experiences such as height among food insecure persons living in the United States. One reason may be because food insecurity measurements in the United States, to date, are based on cross-sectional study design. One study examined how occasional, recurring, or frequent/chronic food insecurity was in the United States using the August 1998 Food Security Supplement to the CPS results (Nord and others, 2002). Their results showed that about two-thirds of food insecure households experienced food insecurity as recurring, whereas about one-fifth experienced it as frequent or chronic (Nord and others, 2002).

Chronic nutritional deficits due to food insecurity have been associated with short height or nutritional stunting in developing countries for several decades (Scrimshaw, 2003; Hakeem, 2001; Martorell and others, 1988). Long term nutritional deficits in the growing years among vulnerable populations such as the food insecure may result in decreased height in adults (Kaluski and others, 2007; Martins and others, 2004). Studies show that people who experience undernutrition in their critical times of growth associate with short height (Martins and others, 2004; Benefice and others, 2001; Dulloo and Girardier, 1993). Such individuals have decreased height for their age (Kaluski and others, 2007; Scrimshaw, 2003). Deficiency in nutritional growth factors, mainly essential nutrients such as calcium, calories, iodine, iron, protein, vitamin A and zinc in the fetal, child and adolescent ages are known to induce nutritional stunting or short height (Scrimshaw, 2003; Giovannucci and others, 1997; Jelliffe and others, 1989).

Several disease risks have been associated with short height. Short adult height is associated with increased risk of CHD and stroke mortality (Silventoinen and others, 2003; Goldbourt and Tanne, 2002). All-cause mortality risk was twice for men below 165 cm compared with taller men (Allebeck and Bergh, 1992). In men, short height associates with increased incidence of prostate cancer (Wright and others, 2007; Andersson and others, 1997).

STATEMENT OF RESEARCH OBJECTIVES

The overall objective of this research was to provide a better understanding of the health and nutritional status of food insecure adults in the United States.

The specific objectives for the first study were to:

1. Determine the associations between adult food insecurity and percent body fat.
2. Determine the associations between food insecurity and adult height.
3. Determine the associations between adult food insecurity and percent body fat stratified by height.
4. Determine the associations between adult food insecurity and BMI stratified by height.

The specific objectives for the second study were to:

1. Determine the associations between adult food insecurity and weight gain >5kg and >10kg during 1 and 10 years.
2. Determine the associations between adult food insecurity and weight gain ≥10% of body weight during 1 and 10 years.
3. Determine the associations between adult food insecurity and BMI.

The specific objectives for the third study were to:

1. Estimate the likelihood of dyslipidemia for food insecure persons compared with fully food secure persons. Dyslipidemia was measured by fasting levels of the following serum lipids:

a. HDL-cholesterol. b. LDL-cholesterol.

c. Total cholesterol. d. Total cholesterol/HDL-cholesterol ratio.

e. LDL-/HDL-cholesterol ratios. F. Triglycerides levels.

2. Estimate the likelihood of elevated plasma glucose for food insecure persons compared with fully food secure persons.

CHAPTER 3

ASSOCIATIONS BETWEEN FOOD SECURITY STATUS AND PERCENT BODY FAT, BODY MASS INDEX AND HEIGHT AMONG MEN AND WOMEN

Abstract

This study determined the associations between adult food insecurity (FI) and percent body fat (%BF), body mass index (BMI) and height, and between FI and %BF, BMI stratified by height. Percent body fat from bioelectrical impedance analysis data for 2,117 men and 1,909 women in the NHANES 1999-2002 were determined. Descriptive statistics and multiple regression procedures were used to examine associations. Age, education, income, race/ethnicity and smoking were included as covariates. Results showed that, compared with their fully food secure counterparts, %BF, height and BMI decreased as FI increased among men. Marginal food security among women who were below median height associated with about 2.0 kg/m^2 increase in BMI, P = 0.042. Marginal food security among women associated with approximately 1.3 cm decrease in height, P = 0.016. However, %BF did not associate with food insecurity among women. In conclusion, food insecurity associates with decreases in %BF, BMI and height among men. Height should be considered in the study of the associations between food insecurity and overweight and obesity in women. The results highlight the need to reinvigorate efforts aimed at alleviating the effects of prolonged as well as brief episodes of food insecurity.

Key words: Percent body fat, body mass index, height, food insecurity, smoking

Introduction

Between 1995 and 2006, the prevalence of adult food insecurity (FI) in the United States, defined as having limited or uncertain availability of nutritionally adequate and safe foods or limited or uncertain ability to acquire acceptable foods in socially acceptable ways (Anderson, 1990; LSRO Expert Panel, 1989), fluctuated between 9.5 and 11.9% (USDA, 2007). Several research reports indicate that food insecure individuals are at increased risk of overweight and obesity (OB) and obesity-related health problems (Holben, 2004; Vozoris and Tarasuk, 2003). Intermediate levels of FI associate with increased BMI in women (Wilde and Peterman, 2006; Adams and others, 2003; Dietz, 1997) and in some cases men (Hanson and others, 2007; Wilde and Peterman, 2006). These associations have been observed to vary by the level and severity of FI (Frongillo and others, 1997). The mechanisms responsible for the positive association between FI and BMI in women have not been established but several plausible explanations have been offered, including socio-economic deprivation, adaptive coping behavior and lack of access to resources (Sarlio-Lahteenkorva, 2001; Olson, 1999; Robertson and others, 1999; Dietz, 1997). These are characteristics indicative of low socio-economic status which associates with decreased height (Kaluski and others, 2007; Hakeem, 2001; Cavelaars and others, 2000).

To our knowledge, nutritional indicators that reflect earlier life experiences, such as height, have not been documented among food insecure adults living in the United States. Short height arising from inadequate nutrition, also termed nutritional stunting, has been observed in developing countries for several decades (Scrimshaw, 2003; Hakeem, 2001). Long term nutritional deficiencies among vulnerable populations such as the food insecure, engender height deficits in adults (Kaluski and others, 2007; Scrimshaw, 2003). Inadequate nutrition can result in inadequate intakes of nutrients essential for linear growth, including iodine, zinc, calcium, vitamin A, protein and calories, which may result in nutritional stunting (Scrimshaw, 2003; Giovannucci and others, 1997). Studies show that people who experience nutritional stunting recover in weight but not in height (Kaluski and others, 2007; Benefice and others, 2001; Dulloo and Girardier, 1993).

Bioelectrical impedance analysis (BIA) is one method used for %BF assessment (Frisard, 2005; Bolanowski and Nilsson, 2001; Kyle and others, 2001). Whereas researchers have examined the associations between FI and OB using BMI, none to our knowledge, examined the associations using %BF derived from BIA. If a positive association exists between FI and BMI among women, a positive association between FI and %BF in women would be expected. The purpose of this study is to determine the associations between FI and %BF, BMI, and whether these associations vary by height.

Research Methods and Procedures

Study sample and data sources

Cross-sectional data from the National Health and Nutrition Examination Survey 1999-2002 (NHANES 1999-2002) were used for this study. The NHANES is a nationally representative survey conducted by National Center for Health Statistics (NCHS) of the Centers for Disease Control and Prevention (CDC). Stratified, multistage probability cluster sampling methods were used in the NHANES. It is an ongoing survey that covers the non-institutionalized US civilian population. A total of 4,026 subjects, comprising 2,117 men and 1,909 women, ages 18-50, who were not pregnant, not lactating, in excellent to fair health, had complete data on BIA (for calculation of %BF), age, body weight, food security status, gender and height were included in this study. Standardized household interview and health examination methods were used to collect all data. Current measured BIA, BMI and weight were obtained from NHANES mobile examination centers. Demographic information for gender, race/ethnicity, level of education and income were obtained from the demographic questionnaire. Current health and smoking status were obtained from the health status, and smoking and tobacco use questionnaires, respectively. NCHS Ethics Review Board approved the survey protocols and informed consent was obtained from all subjects (CDC, 2007a). The procedures for this study were approved locally by the Institutional Review Board, Office of Human Subjects Research, Auburn University.

Food security measure

In the NHANES 1999-2002, depending on the number of affirmatives to 10 items pertaining to adult food insecurity, adults were assigned to one of four food security levels: fully food secure if they affirmed none of the 10 adult items, marginal food security if they affirmed 1-2 items, food insecure without hunger if they affirmed 3-5 items, and food insecure with hunger if they affirmed ≥6 items (Hanson and others, 2007; USDA, 2007). Food security questions asked during the survey referred to food-related circumstances in the past 12 months prior to administration of food security questionnaire (USDA, 2007).

Body fat and height assessment

A bioimpedance spectrum analyzer (HYDRA ECF/ICF 4200; Xitron Technologies, Inc., San Diego, CA) was used for the BIA which involved tetrapolar measurement of whole-body electrical resistance. In the NHANES, BIA examinations were conducted by trained health technicians in the mobile examination centers (CDC, 2007a). In this study, BIA values at 50kHz electrical current were used to estimate fat-free body mass (FFM) by utilizing a prediction equation for adults which has been validated against dual energy x-ray absorptiometry (DEXA) (Kyle and others, 2001). Utilizing this equation, fat-free mass was estimated as: FFM = -4.104 + (0.518 × H^2/R) + (0.231 × weight) + (0.130 × reactance) + (4.229 × gender; males = 1, females = 0). Where H^2/R is height squared divided by resistance (cm^2/Ω). From the estimated FFM, the %BF was calculated as follows (Zhu and others, 2003): %BF = [(body weight-FFM) ÷ body weight] × 100. Percent body fat values were calculated separately for men and women. Participants who were measured in the BIA sample in the NHANES 1999-2002 were within the ages 18-50 y. Inclusion of this age range is understandably due to the fact that body composition and height vary markedly in younger and older persons (Newman and others, 2001; Snead and others, 1993). We found this sample suitable for our study because the associations between FI and OB have been reported among adults. In addition, the use of BMI to assess adiposity in older adults has been questioned (Huffman, 2002; Omran and Morley, 2000).

Height was measured by trained technicians using a stadiometer equipped with an integrated survey information system (CDC, 2007c). Further details on the height and other anthropometric measurements are available elsewhere (CDC, 2007c).

Statistical analysis and covariates

Multiple linear regression models were used to examine the associations between food insecurity and %BF, BMI and height. Due to reported differences in the association between food insecurity and body weight status between men and women, all analyses were stratified by gender (Wilde and Peterman, 2006; Sarlio-Lahteenkorva, 2001). In order to examine the associations between FI and %BF, and BMI at different levels of height, we stratified participants into those below and above median height as follows: for men; below median height was <174.7 cm, above median height was ≥174.7 cm in height, and for women; below median height was <161.7 cm and above median height was ≥161.7 cm in height for this sample.

Statistical analyses were done using STATA 10.0 (STATA Corporation, College Station, Texas) and SAS 9.1.3 (SAS Institute Inc., Cary, NC) statistical software. To correct for MEC sampling design and to apply MEC sampling weights, STATA 10.0 (College Station, TX) was used to estimate all descriptive and inferential statistics (CDC, 2005). Statistically significant associations were tested at $P < 0.05$.

Covariates included in all models were age, education, ethnicity/race, income and smoking status because of reported associations with body weight (Kaluski and others, 2007, Goldbourt and Tanne, 2002; Pi-Syner, 1999). Age, %BF, BMI, height and income were examined as continuous variables whereas education, ethnicity and smoking status were examined as indicator variables. Level of education was classified as less than high school degree and high school degree or higher. Due to small sample sizes, race/ethnicity was collapsed into three categories: Black non-Hispanic, Mexican-American and other Hispanics, and White non-Hispanic plus others. In the NHANES 1999-2002, participants who reported use of 100 cigarettes, pipes 20 times, and cigars 20 times in their life time and currently use tobacco were classified as smokers (Funada and others, 2008). Those who reported previous smoking were classified as ex-smokers. Those who reported never smoking to all were classified as never smokers.

In testing for associations between the main exposure variable, food security status, and the outcome variables; %BF, BMI and height, the fully food secure category was the referent group. The referent categories for the covariates were high school degree or higher, never smoker and non-Hispanic White.

Results

Background characteristics of the subjects are presented in Table 1. Of the 4,026 subjects in the study, 52% were men and 48% were women. Subjects who were fully food secure or marginally food secure together made up 89.0% of this sample. The mean height and BMI of the subjects were; men: 176.66 ± 0.22 cm and 26.76 ± 0.10 kg/m^2; and women: 163.15 ± 0.21 cm and 27.41 ± 0.24 kg/m^2 respectively. The other characteristics of the subjects across the four levels of food security are shown in Table 1.

Table 2 shows the %BF of men and women by food security level. Men who were food insecure without hunger or with hunger significantly associated with lower

%BF than men who were food secure. In men, this pattern did not change after height stratification (Table 3). Compared with fully food secure women, FI did not significantly associate with %BF among women, not even after height stratification (Table 3).

Men who were food insecure without hunger or with hunger associated with significantly lower BMI than men who were fully food secure (Figure 1) irrespective of height. Different patterns of association were observed among women. Before height stratification, the association between FI and BMI among women was not significant after controlling for covariates, particularly income (Table 2). However, after height stratification and controlling for covariates, women who were classified as marginal food security and below median height associated with approximately 2.0 BMI units higher than their fully food secure counterparts, $P < 0.042$, (Table 3). No significant differences in BMI were observed among women who were above median height compared with their fully food secure counterparts (Figure 1).

Men who experienced FI without hunger or with hunger significantly associated with about 2 cm decreases in height compared with fully food secure men. Among women, marginal food security associated with approximately 1.3 cm, $P < 0.016$, decrease in height.

Discussion

A significant finding in this study is that women who were marginally food secure and were below median height associated with increased BMI but not women above median height. Body mass index showed a tendency toward higher values among women who were below median height at all levels of FI. Among women, we found no association between food insecurity and %BF which is a more sensitive measure of adiposity. In addition, unlike BMI, %BF did not vary by height among women. The importance of height in FI and BMI analysis was earlier observed and included as a control variable in a study which reported moderate (P = 0.06) but positive association between FI and BMI (Olson, 1999). Our results suggest that height should be considered when examining the association between food insecurity and BMI.

We found that marginal food security associated with decreased height in women but it was the extreme forms of FI, food insecure without and with hunger, which associated with decreased height in men. The observation that FI associated with decreased height among men and women was not unexpected because nutritional stunting of height results from chronic undernutrition (Scrimshaw, 2003; Hakeem, 2001) which is a possible consequence of FI. It is difficult to glean from available data whether women who were below median height in this study have experienced FI for a longer duration than those who were above median height. However, an earlier report indicated that about two-thirds of food insecure persons in the United States experience FI as recurring while one-fifth experience it as frequent or chronic (Nord and others, 2002).

Low income individuals, a group that largely includes those who are food insecure, associate with decreased height (Kaluski and others, 2007; Cavelaars and others, 2000) probably due to difficulties in obtaining optimum nutrition during their growing years (Kirkpatrick and Tarasuk, 2008; Scrimshaw, 2003; Hakeem, 2001). Ensuring adequate nutrition by alleviating FI would improve adult height and perhaps help to ameliorate its influence on the development and progression of obesity. Improvement in adult height is important because several disease risks have been associated with decreased height. Short adult height is associated with risk of coronary heart disease and stroke mortality (Silventoinen and others, 2003; Goldbourt and Tanne, 2002). All-cause mortality risk was double for men who were below 165 cm in height compared to taller men (Allebeck and Bergh, 1992). Significant association between short height and increased incidence of prostate cancer has been reported (Wright and others, 2007). Previous studies have shown food insecure individuals to be at greater risk of developing many of these chronic diseases (Stuff, 2004; Sharkey, 2003; Vozoris and Tarasuk, 2003). Our finding that FI was associated with decreases in height, underscore the public health importance of nutrition programs that target individuals during the critical times of growth. The positive influences on infant length and wellbeing through federal food assistance programs participation has been reported (El-Bastawissi, 2007; Black and others, 2004).

Percent body fat and BMI showed similar patterns of association across food security levels in men but not in women. Physiological adaptation in women such as leptin-mediated maintenance of critical fat mass in women for reproduction may contribute to obscure differences in %BF across food security levels (Bray and Bouchard, 1997). The levels of FI observed in this population may not indicate calorie shortage among women (Zizza and others, in press). In addition, differences in %BF among women might have been obscured by the already elevated %BF of the referent group in this study, fully food secure women.

The strengths of our study lie in the fact that we assessed two indicators of adiposity, %BF and BMI to study their associations with FI. Another strength is that this analysis accounted for important covariates including smoking status which is common among food insecure persons and influences their dietary intake and composition (Troisi and others, 1991; Klesges and others, 1990) and body weight (Lissner and others, 1992; Manson, 1987). Available literature indicates that, unlike this study, only few controlled for smoking in the study of the associations between FI and BMI (Armour, 2007). However, there is a significant inverse association between smoking and body weight (Manson, 1987). In this study, food security status information covered a reference period of 12 months to improve sensitivity and to provide a more reliable assessment. Another important strength is that the study comprised a large sample of persons in the United States and that the conduct of the study was carefully standardized.

A limitation of this study is that the relationships between FI and %BF, and BMI were based on cross-sectional data which do not permit inferences related to causality (Wilde and Peterman, 2006; Olson, 1999). Bioelectrical impedance analysis is a well recognized method for %BF assessment (Frisard, 2005; Bolanowski and Nilsson, 2001; Kyle and others, 2001). However, assessment of %BF using BIA may not be appropriate for individuals who have extremely high BMI because %BF does not increase linearly with increasing body weight (Flegal 1997; Deurenberg, 1996).

This study shows FI associates with lower %BF, BMI and height in men, and marginal food security associates with decreased height in women. A significant increase in BMI was found only among marginally food secure women who were below the median height. These observations highlight the need for more vigorous public health efforts to alleviate the effects of FI and to improve food security in this population. Longitudinal studies which should include repeated measures of FI, height, weight and adiposity indicators across the life cycle are needed to further elucidate the associations between FI and %BF, BMI and height.

Table 1. Background characteristics of the participants by adult food security status

Characteristic[1]	Fully food secure (n = 3,005)	Marginally food secure (n= 391)	Food insecure w/out hunger (n = 409)	Food insecure with hunger (n = 221)	Sample Total (n= 4,026)
			Mean ± SE		
Age (years)					
Men	34.06 ± 0.37	32.08 ± 0.81	30.64 ± 0.89	30.87 ± 1.43	33.58 ± 0.31
Women	34.87 ± 0.42	32.87 ± 0.76	33.59 ± 0.88	34.40 ± 1.54	34.62 ± 0.35
Weight					
Men	84.78 ± 0.28	82.53 ± 1.26	76.33 ± 1.71	75.47 ± 1.42	83.69 ± 0.31
Women	72.75 ± 0.69	74.84 ± 1.38	72.72 ± 2.19	73.81 ± 2.40	72.95 ± 0.65
Income					
Men	3.31 ± 0.08	1.62 ± 0.11	1.35 ± 0.08	1.18 ± 0.14	3.00 ± 0.08
Women	3.15 ± 0.10	1.51 ± 0.11	1.51 ± 0.19	1.26 ± 0.14	2.85 ± 0.08
			%		
Gender					
Men	52.33	45.22	54.71	50.14	51.82
Women	47.67	54.78	45.29	49.86	48.18
Ethnicity					
White (Non-Hisp)	76.70	44.57	46.20	64.40	72.00
Black (Non-Hisp)	9.82	22.84	17.89	11.65	11.30
Mexican Amer[2]	13.49	32.59	35.91	23.95	16.70
Education					
< High school	15.36	35.54	43.34	40.71	19.62
≥ High school	84.64	64.46	56.66	59.29	80.38
Marital Status					
Married[3]	60.48	55.64	48.08	51.88	58.92
Widowed[4]	10.33	16.03	15.61	20.17	11.53
Never married	29.19	28.33	36.31	27.96	29.56
Smoking					
Never-smoker	54.24	49.33	46.51	31.63	52.42
Ex-smoker	18.63	11.12	11.41	15.52	17.52
Current smoker	27.13	39.54	42.09	52.85	30.06

[1]Includes adults 18-50 y who participated in the NHANES 1999-2002 with complete data on age, gender, BIA, BMI and height. NHANES 1999-2002 design corrections were applied and all estimates were weighted using NHANES four-year MEC sampling weights. [2]Mexican Americans and other Hispanics. [3]Married includes staying with partner. [4]Widowed includes divorce or separated.

Table 2. Percent body fat, body mass index and height categorized by gender and adult food security status

	Food security status[1]			
	Fully food Secure[2]	Marginal food security	Food insecure without hunger	Food insecure with hunger
Men[4]	(n = 1573)[3]	(n = 187)	(n = 234)	(n = 123)
Body fat (%)	24.91 ± 0.18	26.01 ± 0.70	22.82 ± 0.92*	22.23 ± 0.75*
BMI (kg/m^2)	27.11 ± 0.10	27.52 ± 0.47	25.59 ± 0.55*	24.86 ± 0.52*
Height (cm)	177.32 ± 0.20	176.11 ± 0.72	174.74 ± 0.86*	174.62 ± 0.88*
Women[4]	(n = 1432)	(n = 204)	(n = 175)	(n = 98)
Body fat (%)	35.94 ± 0.27	35.66 ± 0.63	35.66 ± 0.93	35.00 ± 1.03
BMI (kg/m^2)	27.24 ± 0.22	28.13 ± 0.58	27.23± 0.78	26.94 ± 0.98
Height (cm)	163.54 ± 0.15	162.26 ± 0.50*	163.00 ± 0.59	163.66 ± 0.76

[1]Includes adults 18-50 y who participated in the NHANES 1999-2002, adjusted for age, education, ethnicity, income and smoking. NHANES 1999-2002 design corrections were applied and all estimates were weighted using NHANES four-year MEC sampling weights. [2]Referent group. [3]Number of participants is in parenthesis. [4]Mean ± SE. *An asterisk indicates significant differences from the food secure category in the same row, $P < 0.05$.

Table 3. Percent body fat and body mass index categorized by adult food security and height

	Food security status[1]			
	Fully food Secure[2]	Marginal food security	Food insecure w/out hunger	Food insecure with hunger
Men[4]				
Below median height (<174.7 cm)	(n = 669)[3]	(n = 108)	(n = 155)	(n = 79)
Body fat (%)	23.78 ± 0.26	24.36 ± 1.07	21.60 ± 1.18*	21.57 ± 1.22*
BMI (kg/m^2)	26.98 ± 0.21	27.43 ± 0.72	25.51 ± 0.74*	25.55 ± 0.66*
Above median height (≥ 174.7 cm)	(n = 904)	(n = 798)	(n = 79)	(n = 44)
Body fat (%)	25.53 ± 0.20	26.92 ± 1.20	23.55 ± 1.34	22.01 ± 1.34*
BMI (kg/m^2)	27.18 ± 0.13	27.53 ± 0.72	25.83 ± 0.69*	24.08 ± 0.93*
Women[4]				
Below median height (<161.7 cm)	(n = 646)	(n = 117)	(n = 109)	(n = 47)
Body fat (%)	35.76 ± 0.43	35.95 ± 0.95	36.15 ± 1.05	33.94 ± 1.60
BMI (kg/m^2)	27.72 ± 0.36	29.60 ± 0.97*	28.03 ± 0.93	28.59 ± 1.56
Above median height (≥ 161.7 cm)	(n = 786)	(n = 87)	(n = 66)	(n = 51)
Body fat (%)	36.06 ± 0.29	35.33 ± 0.98	35.16 ± 1.52	35.36 ± 1.00
BMI (kg/m^2)	26.97 ± 0.26	26.69 ± 0.84	26.70 ± 1.40	25.73 ± 0.96

[1]Includes adults 18-50 y who participated in the NHANES 1999-2002. NHANES 1999-2002 design corrections were applied and all estimates were weighted using NHANES four-year MEC sampling weights. [2]Referent group, does not include marginal food security. [3]Number of participants is in parenthesis. [4]Mean ± SE, adjusted for age, education, income, race and smoking status. *Asterisk indicates significant differences from the food secure category in the same row, $P < 0.05$.

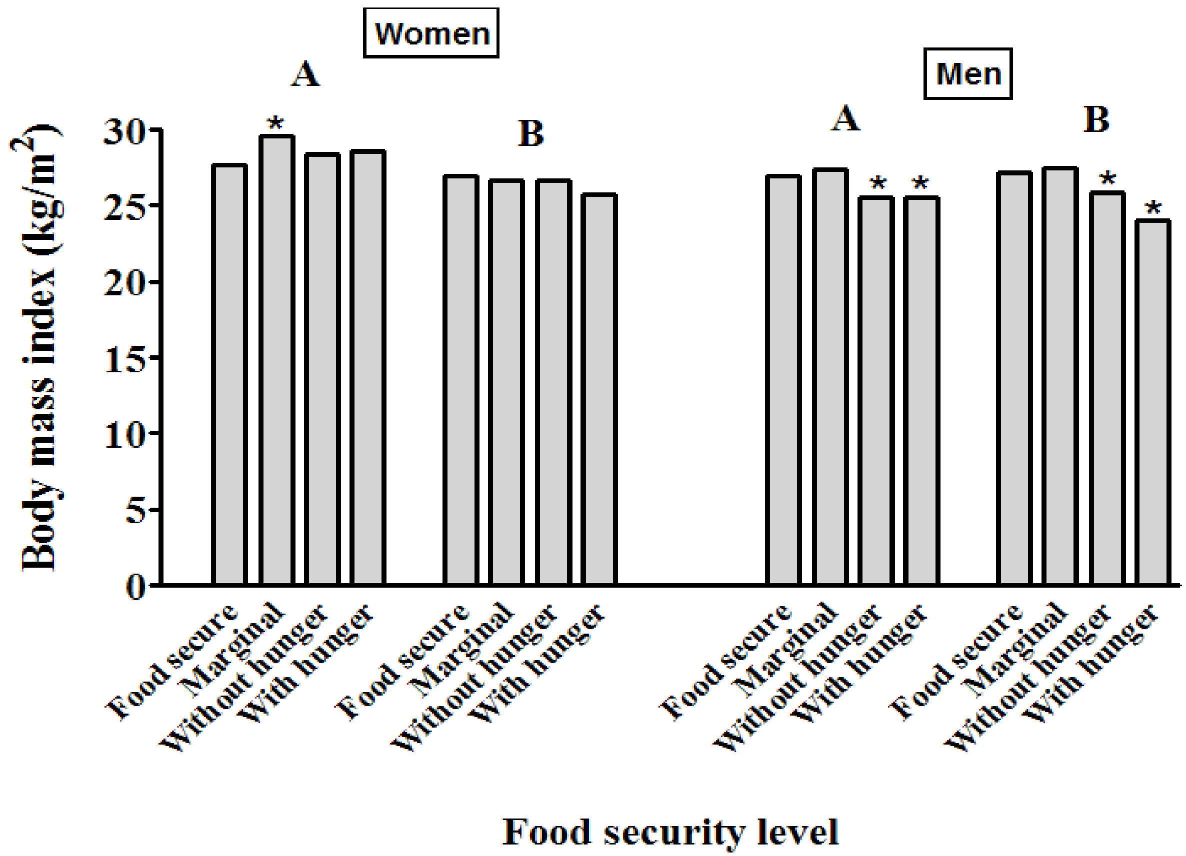

Figure 1. Body mass index of men and women categorized by food security status and height. **A**: below median height, **B**: above median height. Adjusted for age, education, ethnicity, income and smoking. NHANES 1999-2002 MEC four-year full sampling weights and design corrections were applied. The fully food secure category was the referent group. *Significantly different from the fully food secure group, $p < 0.05$.

CHAPTER 4

ADULT FOOD INSECURITY IS ASSOCIATED WITH GREATER BODY WEIGHT GAIN DURING ONE AND TEN YEARS

Abstract

This study determined the associations between adult food insecurity and subsequent weight gain over one and ten years in men and women using multiple specifications. Data from the 1999-2002 National Health and Nutrition Examination Surveys (NHANES) were analyzed. Descriptive statistics and multiple logistic regression procedures were used to examine associations while controlling for age, education, income, race/ethnicity and smoking. Weight gain was calculated as the differences between current technician-measured body weight and self-reported body weight 1 and 10 years ago. Prevalence of weight gain >5kg, >10kg and ≥10%, in 1 and10 years were assessed. The prevalence of obesity was also assessed. Results showed that, compared with the fully food secure, marginal food security among men associated with higher prevalence of weight gain >10kg in 1 year. The prevalence of weight gain >5kg and >10kg in 1 year was significantly higher among marginally food secure and food insecure women. Food insecurity without hunger among women associated with weight gain >5kg in 1 year and >10kg in past 10 years. Food insecurity associated with higher prevalence of weight gain ≥10% in 1 year among women and in 10 years among men. The earlier reported associations between food insecurity and overweight and obesity among women and marginally food secure men were observed in this study. In conclusion, marginal food security among men and food insecurity among women associated with greater weight gain. Longitudinal studies on food insecurity, its transitions and timing in life, coping behaviors and food consumption patterns are needed to enable researchers to elucidate the associations between food insecurity and weight gain.

Key words: Food security, body weight gain, obesity, body mass index, smoking

Introduction

Food insecure persons have limited or uncertain availability of nutritionally adequate and safe food or limited or uncertain ability to acquire acceptable foods in socially acceptable ways (Bickel, 1999; Carlson and others, 1999). Between 1998 and 2005, the prevalence of adult food insecurity in the United States ranged from 9.5 to 11.9% (Nord and others, 2005). Within this period, about two-thirds reported food insecurity as recurring and about one-fifth reported it as frequent or chronic (Nord and others, 2002). Food insecurity associates with overweight and obesity among women (Adams and others, 2003; Townsend and others, 2001; Dietz, 1995) and in some cases men (Wilde and Peterman, 2006). The associations between food insecurity and overweight and obesity predispose food insecure individuals to several health risks, including kidney and gall bladder disease, arthritis, coronary heart disease and type 2 diabetes as well as increased health care cost and decreased life expectancy in younger ages (Holben, 2004; Shin-Yi, 2004; Fontaine, 2003; Peeters, 2003). However, these associations tend to vary by the level and severity of food insecurity (Frongillo and others, 1997).

Besides the use of the National Heart Lung and Blood Institute (NHLBI) expert panel (NHLBI Expert Panel, 2000) BMI guidelines, obesity-related disease risks have been assessed using other anthropometric indices including absolute and percentage changes in body weight and BMI, and body girth measures such as waist and hip circumferences (Wilde and Peterman, 2006; Kaleta and others, 2005; Wannamethee and others, 2001). Even though BMI is easy to measure, suitable for most age groups and correlates highly with body fatness, morbidity and mortality (Shin-Yi, 2004; Aronne, 2002; Jackson and others, 2002), there are several limitations to its use. Certain people who are overweight by BMI standards do not have excess body fat, while others have BMI within the normal range but have excess body fat (Martins and others, 2004; Deurenberg and others, 1998). In addition, people who experienced under-nutrition, such as those food insecure, associate with short height (Martins and others, 2004; Benefice and others, 2001; Dulloo and Girardier, 1993). However, BMI is not independent of height (Bagust and Walley, 2000; Willett, 1998; Flegal, 1997). In cognizance of the limitations of BMI, re-examination of the association between adult food insecurity and weight status by studying long-term changes in body weight is warranted.

To date, few studies have examined the associations between food insecurity and body weight gain by using actual individual weight gain in men and women (Jones and Frongillo, 2007; Wilde and Peterman, 2006) but none had controlled for smoking status or used multiple specifications. Smoking is common with the food insecure and influences both dietary intake and composition (Troisi and others, 1991; Klesges and others, 1990) and weight gain (Lissner and others, 1992; Klesges and Klesges, 1988). In this study, the associations between food insecurity and weight gain during one and ten years in both men and women were examined using different specifications.

Research Methods and Procedures

Study Sample and Data Sources

The NHANES 1999-2000 and 2001-2002 cross-sectional data collected by the National Center for Health Statistics (NCHS) were pooled for this study. The NHANES is a nationally representative survey conducted by the NCHS of the Centers for Disease Control (CDC) on yearly basis. The NHANES which uses stratified, multistage probability cluster sampling method is an ongoing survey that covers the non-institutionalized US civilian population (CDC, 2007a). In the NHANES 1999-2002, survey weights indicating the probability of being sampled for analysis were assigned to each participant, which made the sample representative of the United States population. Standardized household interview and health examination methods were used to collect all data.

The study of the association between food insecurity and body weight gain in one year included data from 5,311 participants, comprising 2,626 men and 2,685 women. Data from participants who were within ages 18-50 years, who were not pregnant, not lactating, had health status excellent to fair, and had complete information on age, BMI, current measured body weight, self-reported body weight 1 year ago, food security status, gender and height were included in this study. Only data from those aged 18-50 years were included because body composition and height vary markedly in younger and older persons (Newman and others, 2001; Snead and others, 1993), while the use of BMI to assess adiposity in older adults had been questioned (Huffman, 2002; Omran and Morley, 2000). In addition, the association between food insecurity and obesity was reported among adults. The study of body weight gain in ten years included a subsample of 2,124 comprising 1,068 men and 1,056 women. This is because in the NHANES 1999-2002, body weight ten years ago was obtained from participants 36 years of age and older (CDC, 2006). With the exception of the age difference, this subsample had fairly similar characteristics to the parent sample.

NCHS Ethics Review Board approved the survey protocols and informed consent was obtained from all subjects (CDC, 2007a). The procedures for this study were approved locally by the Institutional Review Board, Office of Human Subjects Research, Auburn University.

Food security measure

In the NHANES 1999-2002, adults were classified as fully food secure, marginally food secure, food insecure without hunger and food insecure with hunger depending on the number of affirmatives to a subset of 10 adult items from the U.S. 18-item Food Security Survey Module (USDA, 2004). Food security questions asked during the survey referred to food-related circumstances over the past 12 months. Some of the adult questions included: In the last 12 months; “did you ever eat less than you felt you should because there wasn’t enough money for food?”, “were you ever hungry, but didn’t eat, because you couldn’t afford enough food?”, and “did you or other adults in your household ever not eat for a whole day because there wasn’t enough money for food?” (Gulliford, 2006b; Nord and others, 2005). Participants were deemed “fully food secure" if they gave no affirmative response, "marginal food security" if they gave affirmative responses to 1-2 items, "food insecure without hunger" if they gave 3-5 affirmative responses and "food insecure with hunger" if they gave ≥6 affirmative responses (USDA, 2004). The NHANES 1999-2002 questionnaire data files contained socio-demographic information useful for this study. Demographic information on age, gender, race/ethnicity, level of education and income was obtained from the demographic questionnaire. Current health and smoking status were obtained from the hospital utilization and access to care, and smoking and tobacco use questionnaires, respectively. In this study, the adult food security scale was used because the influences of food insecurity could vary across household members (Kaiser and others, 2002; Dixon and others, 2001; Hamilton and others, 1997) and also adults are the first to adopt coping behaviors to food insecurity including limiting of quantity and quality of foods consumed or skipping of meals (Kaiser and others, 2002).

Body Weight Gain Measurement

In the NHANES 1999-2002, technician-measured current body weight, current self-reported body weight, self-reported body weight 1 and 10 years ago, and current BMI were obtained from the Mobile Examination Centers (MEC). Self-reported current and previous body weight data were obtained from the weight history questionnaire. In the MEC, body weight was measured by trained technicians who were also responsible for quality control (CDC, 2007c). Standard protocols were followed during the body weight measurement. Body weight was measured by using a Toledo digital weighing scale (CDC, 2007c). Participants were instructed to stand motionless in the center of the scale platform facing the recorder, hands at side, and looking straight ahead, the body weight was recorded by an automated system (CDC, 2007c).

Weight gain was calculated as the difference between technician-measured current body weight and self-reported body weight 1 and 10 years ago (Wilde and Peterman, 2006; Kaleta and others, 2005). Reliability of respondents' self-reported body weight was assessed by correlating the technician-measured current body weight with the self-reported current body weight. Because of the high correlation, r = +0.97, between the self-reported current body weight and technician-measured current body weight, the self-reported body weights 1 and 10 years ago were deemed reliable.

Three weight gain specifications were used: >5kg, >10kg and ≥10%, of body weight (Funada and others, 2008). Due to reported significant health risks associated with weight gain of 5kg or more (Wilde and Peterman, 2006; Kaleta and others, 2005; Willet and others, 1995), a significant weight gain specification of >5kg was chosen (Funada et al, 2008). Participants were deemed to have stable weight if their body weight change was 5kg or less and gained weight if >5kg (Funada and others, 2008; Kaleta and others, 2005). Weight gain of 10kg in women after 18 years doubles the risk of CVD (Aronne, 2002). For this reason and to improve our ability to detect differences across food security levels, a higher weight gain, 10kg, specification was also used. In this case, a weight gain cut-off of >10kg was used. Body weight gain as a percentage of the body weight 1 and 10 years ago was calculated as the ratio of the difference between the current body weight and body weight 1 or 10 years ago times 100. A specification of ≥10% was used to indicate clinically significant percentage increase in body weight because ≥10% or more increase in body weight is associated with significant increase in mortality among adults (Wannamethee and others, 2001).

Two time points for weight gain were used: weight gain in 1 year and weight gain in 10 years. Because in the NHANES, self-reported body weight 10 years ago was obtained only from adults aged 36 years or older, the study of weight gain during 10 years involved only participants aged 36 years or older. In this analysis, because there were inadequate sample sizes for participants who lost weight or who were underweight, and because the factors for weight gain and weight loss differ (Ali and Lindstrom, 2005), the analysis focused on weight gain and its associations with food insecurity, and did not include those who lost weight.

Due to the extensively reported associations between food insecurity and overweight and obesity, and to enable comparison with published literature, the prevalence of overweight and obesity in relation to food security status was assessed. This was achieved using BMI guidelines of the NHLBI Expert Panel (2000) to categorize participants as either underweight (BMI <18.5 kg/m^2), normal (BMI=18.5-24.9 kg/m^2), overweight (BMI 25-29.9 kg/m^2) or obese (BMI ≥30 kg/m^2) (Expert Panel, 1998).

Statistical Analysis and Covariates

Body weight status associates with several environmental variables. Within the limitations of the available data set, the analysis controlled for age, education, income, race/ethnicity and smoking status (Armour, 2007; Kaluski and others, 2007; Davison, 2002). In the NHANES 1999-2002, sample sizes were small for some race\ethnic groups. Therefore, race/ethnicity groups were collapsed into three categories: Black (non-Hispanic), Mexican-American and other Hispanics, and White (non-Hispanic). A dichotomous variable was created for income as income <185% and ≥185% of Federal poverty threshold. Participants who reported use of 100 cigarettes, pipes 20 times, and cigars 20 times in their life time and currently use tobacco were classified as smokers (Funada and others, 2008). Those who reported previous smoking were classified as ex-smokers. Those who reported never smoking to all were classified as never smokers.

Data analyses were performed using SAS 9.1.4 (SAS Institute Inc., Cary, NC) and STATA 10.0 statistical software (STATA Corporation, College Station, Texas). The NHANES 1999-2000 and 2001-2002 data files were concatenated to obtain the study sample. Per recommendation from data release documentation (CDC, 2007d) and to provide population-representative estimates, all estimates were weighted using the MEC four-year sampling weights. Survey design corrections were applied to correct for complex NHANES survey design. Weighted data were analyzed using STATA 10.0 statistical software (Alaimo and others, 2001).

Gender-stratified descriptive statistics were performed categorized by food security status. Multiple logistic regression procedures were performed to estimate odds ratios (OR) for significant weight gain, weight gain >5kg, >10kg and ≥10%, by food insecurity status while controlling for covariates: age, education, income, race/ethnicity and smoking. Bivariate associations between food insecurity and weight gain, overweight and obesity were tested by using a χ^2 test. Age grouping followed the U.S. Census 2000 format (U.S. Census Bureau, 2007). In the multiple regression analysis, the referent groups were: fully food secure, age 18-24 year group, weight gain ≤5kg,

≤10kg and <10% (where appropriate), never smoker and White (non-Hispanic), high school degree or higher, and income ≥185 of federal poverty threshold. In the assessment of weight gain during 10 years, the referent age group was the 35-44 year group. During the analysis, the categorical variables: education, income, race/ethnicity, and smoking were entered as indicator variables. Statistically significant differences were tested at $p < 0.05$.

Results

Sample Characteristics and Adult Food Security Status

Table 1 shows the background characteristics of the participants. Among the 5,311 participants, about half were men and the other half were women. Most of the participants were fully food secure: men, 82.46%; and women, 82.00%. Participants in the two food insecurity categories: food insecure without and with hunger, made up 11.01% of the sample, close to the national adult food insecurity prevalence of 10.5% reported around the same period 2002 (Nord and others, 2005). Very high correlations between technician measured current body weight and self-reported current body weight for men, r = +0.973 and women, r = +0.970, were observed.

Food security status and body weight gain

Mean body weight and weight gain during one and ten years are shown in Table 2. Food insecure men and women associated with higher mean weight gain during one and ten years (Table 2). About 20% of men and 32% of women gained >5kg in 1 year while over half gained >5kg in 10 years (Table 3). Among men, food insecurity did not associate with weight gain >5kg or >10kg in 1 and 10 years. Significantly greater percentage of marginally food secure, food insecure without and with hunger women associated with weight gain greater than both 5kg and 10kg in 1 year (Figure 1). Food insecurity without hunger among women associated with higher prevalence of weight gain >5kg and >10kg in 10 years (Table 3).

Results from the multiple logistic regression analysis, which controlled for covariates, showed that food insecure men were equally likely as the fully food secure men to gain weight >5kg in 1 year. Women who were food insecure without hunger associated with greater probability to gain >5kg in 1 year compared with fully food secure women (Table 4). Food insecure women were equally likely as the fully food secure women to gain weight >5kg in 10 years. Both men and women were equally likely as their fully food secure counterparts to gain >10kg in past 10 years.

Compared with their fully food secure counterparts, the prevalence of weight gain ≥10% of body weight in the past 10 years was significantly higher for food insecure men (Table 5). The prevalence of weight ≥10% in 1 year was significantly higher for food insecure women. In addition, the prevalence of weight gain ≥10% in 10 years was significantly higher for women who were food insecure without hunger (Figure 2).

In the multiple logistic regression analysis, food insecure men and women were equally likely as their fully food secure counterparts to gain weight ≥10% in 1 and 10 years (Table 5).

Food security status and overweight and obesity

Compared with the fully food secure men, food insecurity without hunger associated with lower prevalence of overweight among men (Table 6). The prevalence of obesity was higher among women who were either marginally food secure or food insecure without hunger (Table 6). Food insecurity with hunger associated with appreciably higher prevalence of overweight among women, $P < 0.07$.

In the multiple logistic regression analysis, men who were marginally food secure were more likely to be obese compared to their fully food secure counterparts (Table 7). Women who were food insecure without hunger were more likely to be obese whereas women who were food insecure with hunger were more likely to be overweight.

Discussion

In this study, there were significantly positive associations between food insecurity and weight gain. In women, significantly positive associations between food insecurity and weight gain showed up at both lower and higher specification. This observation strengthens evidence that food insecurity among women pose greater risk of overweight and obesity (Wilde and Peterman, 2006; Adams and others, 2003; Townsend and others, 2001; Dietz, 1995).

It appears that significant associations between food insecurity and weight gain are found depending on the weight gain specification used. Using a clinical cut-off of >2.3kg, Jones and Frongillo (2007) did not find significant associations between food insecurity and weight gain among women. This was probably due to the lower specification used compared to the specification of >5kg used in the present study. In fact, the mean weight gain of gainers in one year in the present study was above the 2.3kg cut-off at all levels of food security. Therefore this lower cut-off was not applicable to our sample. In this study, there was higher prevalence of weight gain, both at the 5kg and 10kg specifications, among women who were food insecure without hunger.

The observed associations between food insecurity and greater weight gain imply that such individuals could be predisposed to health risks associated with increased weight gain. Long term weight gain associates with greater risk of type 2 diabetes, CVD and other obesity-related morbidity and mortality (Bray, 1998; Willett and others, 1995). Weight gain of 5-10kg or more increases these risks significantly (Bray, 1998; Willett and others, 1995). Weight gain ≥5kg was significantly associated with increased risk of CVD including IHD and hypercholesterolemia (Kaleta and others, 2005).

Significant prevalence of weight gain ≥10% of body weight among food insecure women was observed in 1 year whereas it was observed in 10 years among food insecure men. Food insecurity without hunger among women associated with appreciable prevalence of weight gain ≥10% during 10 years. Using the ≥10% weight increase specification, food insecure men associated with higher weight gain in 10 years whereas food insecure women associated with higher weight gain in 1 year.

The observed associations between food insecurity and overweight and obesity were generally similar to what were observed for the analysis of weight gain. Marginal food security and intermediate-level food insecurity associated with obesity among men and women, respectively. Reports from other studies indicate that while the most severe form of food insecurity may not associate with weight gain (Sarlio-Lahteenkorva and Lahelma, 2001; Frongillo and others, 1997), intermediate levels may promote weight gain through coping behaviors associated with food shortage (Townsend and others, 2001; Frongillo and others, 1997). Preference for low-cost energy-dense foods (Drewnowski and Specter, 2004; Gulliford and others, 2003; Kaiser and others, 2002) reinforced by the pleasing taste of sugar and fat (Drewnowski and Specter, 2004; Holben, 2004) are some of the reasons food insecurity may associate with overweight and obesity. Due to uncertain access to adequate food, individuals who are food insecure may over-consume when food is available (Gulliford and others, 2006a; Cook and others, 2004; Townsend, 2001; Polivy, 1996). Among the under-nourished, metabolic changes may occur which may result in more efficient utilization of food energy or conservation of fat (Martins and others, 2004; Benefice and others, 2001; Dulloo and Girardier, 1993).

The strengths of our study lie in the fact that this analysis accounted for important covariates including smoking status which is common among food insecure persons and influences their dietary intake and composition (Troisi and others, 1991; Klesges and others, 1990) and body weight (Lissner and others, 1992; Manson, 1987). Unlike this study, only few studies have controlled for smoking in the study of the associations between FI and BMI (Armour, 2007). However, there is a significant inverse association between smoking and body weight (Manson, 1987). Another important strength is that food security status information covered a reference period of 12 months to improve sensitivity and to provide a more reliable assessment. In addition, this study included a large sample of persons in the United States and that the conduct of the study was carefully standardized (USDA, 2007).

One limitation of this study is that self-reported body weight data were used. Self-reported body weight data are subject to reporting and non-response bias depending on how they were obtained (Jones and Frongillo, 2007; Rowland, 1990). However, several studies have found self-reported body weight data reliably accurate (Jones and Frongillo, 2007; Wilde and Peterman, 2006; Bendixen and others, 2004). The very high correlations between technician measure current body weight and self-reported current body weight for participants in this study affirm the reliability of the self-reported body weight data. In this study, the relationships between food insecurity and body weight gain were based on cross-sectional data which do not permit causal inferences (Wilde and Peterman, 2006; Olson, 1999). However, the observed associations between food insecurity and weight gain strengthen the circumstantial evidence that intermediate-level food insecurity contributes to weight gain and hence obesity.

In conclusion, there were significantly positive associations between food insecurity and weight gain among men and women. Intermediate-level food insecurity among women associates with greater weight gain, and overweight and obesity. The earlier reported associations between food insecurity and overweight and obesity among women and marginally food secure men were present among this sample.

Improving food security may ultimately contribute significantly to efforts towards alleviation of overweight and obesity, and ameliorate subsequent obesity-related morbidity and mortality. Studies which go beyond just examination of contextual associations are needed to ascertain causal influences of food insecurity on weight gain. Longitudinal studies on food insecurity, its transitions and timing in life, coping strategies and adaptive behaviors, food consumption patterns, health symptoms and social behavior are needed during the critical stages of life to enable researchers elucidate any causal associations between food insecurity and weight status.

Table 1. Background characteristics of the participants by adult food security status

Characteristic[1]	Food secure (n = 3,959)	Marginal food security (n= 507)	Food insecure without hunger (n = 540)	Food insecure with hunger (n = 305)	Population Total (n= 5311)
			Percent %		
Gender					
Men	51.15	47.18	53.36	50.94	51.01
Women	48.85	52.82	46.64	49.06	48.99
Ethnicity					
White (Non-Hisp)	76.41	45.01	47.08	59.89	71.65
Black (Non-Hisp)	10.48	21.71	19.09	15.53	12.02
Mexican Amer[2]	13.11	33.28	33.83	24.59	16.33
Highest Education					
< High school	16.03	34.76	43.54	42.26	20.26
≥ High school	83.97	65.24	56.46	57.74	79.74
Income					
< 185%	29.25	72.88	76.37	84.93	37.63
≥ 185%	70.75	27.12	23.63	15.07	62.37
Smoking					
Never-smoker	52.82	51.13	45.92	32.45	51.35
Ex-smoker	18.71	11.57	13.92	14.87	17.75
Current smoker	28.46	37.30	40.16	52.68	30.90
			Mean ± SE		
Age (years)					
Men	34.74 ± 0.38	33.18 ± 0.69	31.62 ± 0.77	31.90 ± 0.90	34.30 ± 0.30
Women	35.10 ± 0.36	32.40 ± 0.72	34.24 ± 0.65	34.44 ± 1.51	34.82 ± 0.29
Body weight (kg)					
Men	85.81 ± 0.37	86.73 ± 1.91	79.57 ± 1.80	81.58 ± 2.96	85.26 ± 0.43
Women	73.07 ± 0.60	74.97 ± 1.38	76.98 ± 2.21	74.45 ± 2.54	73.51 ± 0.58
BMI (kg/m^2)					
Men	27.22 ± 0.13	28.46 ± 0.64	26.24 ± 0.57	26.65 ± 0.73	27.21 ± 0.13
Women	27.33 ± 0.22	28.98 ± 0.51	29.46 ± 0.82	28.08 ± 0.92	27.61 ± 0.21

[1]Includes adults 18-50 years who participated in the NHANES 1999-2002 with complete data on age, current measured body weight, self-reported body weight 1 year ago, BMI and gender. All estimates were weighted using NHANES four-year MEC sampling weights and NHANES 1999-2002 design corrections were applied. [2]Mexican Americans and other Hispanics.

Table 2. Summary of current and self-reported body weight in relation to adult food security status

Food security status[1]	n[2]	Current measured body weight (kg)	Self-reported body weight 1 year ago (kg)	n	Self-reported body weight 10 years ago (kg)
			Mean ± SE		
Men					
Fully food secure	1940	85.81 ± 0.37	86.11 ± 0.38	836	82.51 ± 0.63
Marginal food security	236	86.73 ± 1.91	87.96 ± 2.26	83	80.00 ± 1.84
Food insecure without hunger	288	79.57 ± 1.80	80.44 ± 1.77	87	79.27 ± 2.09
Food insecure with hunger	162	81.58 ± 2.96	81.67 ± 2.98	57	77.02 ± 4.59
Men total	2626	85.26 ± 0.43	85.65 ± 0.44	1068	82.04 ± 0.60
Women					
Fully food secure	2019	73.07 ± 0.60	71.41 ± 0.55	811	64.96 ± 0.63
Marginal food security	271	74.97 ± 1.38	73.50 ± 1.36	84	65.49 ± 2.25
Food insecure without hunger	252	76.98 ± 2.21	75.15 ± 2.24	101	71.66 ± 3.12
Food insecure with hunger	143	74.45 ± 2.54	72.81 ± 2.53	60	67.21 ± 2.56
Women total	2685	73.51 ± 0.58	71.85 ± 0.53	1056	65.48 ± 0.64

[1]All estimates were weighted using NHANES four-year MEC sampling weights, NHANES 1999-2002 design corrections were applied. Includes adults 18-50 y who participated in the NHANES 1999-2002 with non-missing data for age, current measured body weight, self-reported body weight 1 year ago, BMI and gender. [2]Number of participants in each category.

Table 3. Weight gain greater than five or ten kilograms in one and ten years in relation to food security status

Adult food security status[1,2]	n	Lost >5kg	Stable weight (gained ±5kg)	Gained[3] > 5kg	Gained > 10kg
			In 1 year (%)		
Men					
Food secure	1940	16.10	64.40	19.50	6.70
Marginal food security	236	17.06	61.19	21.74	11.08
Food insecure without hunger	288	18.87	60.44	20.69	9.05
Food insecure with hunger	162	19.91	57.50	22.60	7.04
Men total	2626	16.52	63.62	19.86	7.14
Women					
Food secure	2019	12.60	57.07	30.33	13.39
Marginal food security	271	11.26	49.43	39.31*	21.19*
Food insecure without hunger	252	14.23	44.82	40.95*	19.96*
Food insecure with hunger	143	16.55	42.22	41.23*	21.40*
Women total	2685	12.78	55.10	32.12	14.66
			In 10 years (%)		
Men					
Food secure	836	9.86	38.53	51.61	29.76
Marginal food security	83	17.49	34.53	47.98	36.93
Food insecure without hunger	87	15.58	25.65	58.77	35.87
Food insecure with hunger	57	32.24	23.56	44.19	33.61
Men total	1068	11.26	37.20	51.54	30.56
Women					
Food secure	811	6.35	28.61	65.05	42.37
Marginal food security	84	2.95	24.87	72.17	45.39
Food insecure without hunger	101	3.76	21.15	75.09*	63.06*
Food insecure with hunger	60	18.17	24.87	56.96	46.03
Women total	1056	6.57	27.81	65.62	43.87

[1]All estimates were weighted using NHANES four-year MEC sampling weights, NHANES 1999-2002 design corrections were applied. [2]Includes adults 18-50 y who participated in the NHANES 1999-2002 with complete data on age, current measured body weight, self-reported body weight 1 year ago, BMI and gender. [3]Weight change was the difference between current body weight and body weight one or ten years ago, respectively. *Values with asterisks in the same column are significantly different from fully food secure category, $P < 0.05$.

Table 4. Weight gain during one and ten years in relation to food security status

Adult food security status[1]	n	In 1 year[2]	In 10 years[2]
		OR for weight gain > 5kg (95% CI)[3,4]	
Men			
Marginal food security	236	1.14 (0.60-2.15)	0.75 (0.41-1.38)
Food insecure without hunger	288	0.84 (0.48-1.47)	1.30 (0.62-2.70)
Food insecure with hunger	162	1.12 (0.56-2.21)	0.93 (0.45-1.92)
Women			
Marginal food security	271	1.24 (0.84-1.83)	1.09 (0.53-2.23)
Food insecure without hunger	252	1.48 (1.02-2.15)*	1.01 (0.52-1.94)
Food insecure with hunger	143	1.29 (0.79-2.12)	0.58 (0.31-1.11)
		OR for weight gain ≥ 10% (95% CI)	
Men			
Marginal food security	236	1.11 (0.52-2.34)	1.31 (0.69-2.48)
Food insecure without hunger	288	0.51 (0.23-1.14)	1.51 (0.76-2.98)
Food insecure with hunger	162	0.69 (0.38-1.24)	1.09 (0.45-2.60)
Women			
Marginal food security	271	1.25 (0.73-2.15)	0.81 (0.44-1.48)
Food insecure without hunger	252	1.16 (0.67-2.02)	1.18 (0.57-2.44)
Food insecure with hunger	143	1.40 (0.72-2.84)	0.73 (0.29-1.82)

[1]Includes adults 18-50 y who participated in the NHANES 1999-2002 complete data on age, current measured body weight, self-reported body weight 1 year ago, BMI and gender. All estimates were weighted using NHANES four-year MEC sampling weights, NHANES 1999-2002 design corrections were applied. [2]Weight gain was the difference between current body weight and body weight one or ten years ago, respectively. [3]Odds ratios compared with fully food secure category, 95 % confidence interval in parenthesis. [4]Logistic regression analysis controlled for age, education, ethnicity, income and smoking. *Significantly higher than the fully food secure category in the same column, $p < 0.05$.

Table 5. Weight gain as percentage of body weight one and ten years ago in relation to adult food security status

Food security status[2]	% Adults in category[1]					
	n	Gained < 10% body weight[3]	Gained ≥ 10% body weight	n	Gained < 10% body weight	Gained ≥ 10% body weight
	In 1 year			In 10 years		
Men						
Food secure	1940	83.19	16.81	836	55.97	44.03
Marginal food security	236	77.02	22.98	83	41.14	58.86*
Food insecure without hunger	288	80.32	19.68	87	35.55	64.45*
Food insecure with hunger	162	77.07	22.93	57	40.66	59.34*
Men total	2626	82.27	17.73	1068	53.82	46.18
Women						
Food secure	2019	68.44	31.56	811	35.22	64.78
Marginal food security	271	54.13	45.87*	84	36.60	63.40
Food insecure without hunger	252	59.16	40.84	101	25.90	74.10
Food insecure with hunger	143	45.22	54.78*	60	33.01	66.99
Women total	2685	65.75	34.25	1056	34.64	65.36

[1]Weight gain was the difference between current body weight and body weight one or ten years ago, respectively.
[2]Includes adults 18-50 year who participated in the NHANES 1999-2002 with complete data on age, current measured body weight, self-reported body weight 1 year ago, BMI and gender. All estimates were weighted using NHANES MEC four-year survey weights. NHANES 1999-2002 design corrections were applied. *Significantly higher than the fully food secure category in the same column, $p < 0.05$.

Table 6. Overweight and obesity among men and women in relation to food security status using current measured body mass index

Adult food security status[1,2]	n	Underweight[3] (BMI < 18.5)	Normal weight[4] (BMI 18.5-24.9)	Overweight (BMI 25-29.9)	Obese (BMI ≥ 30)
		Percent (%)			
Men					
Fully food secure	1940	1.41	35.01	40.32	23.27
Marginal food security	236	0.81	25.00	39.68	29.51
Food insecure without hunger	288	3.27	45.60	30.75*	20.38
Food insecure with hunger	162	2.24	40.74	35.26	21.76
Men total	2626	1.53	35.67	39.40	23.40
Women					
Fully food secure	2019	3.68	41.89	25.90	28.53
Marginal food security	271	1.93	30.40	27.92	39.76*
Food insecure without hunger	252	4.82	28.80	22.53	43.84*
Food insecure with hunger	143	8.81	22.75	34.65[†]	33.79
Women total	2685	3.86	39.37	26.25	30.52

[1]Includes adults 18-50 years who participated in the NHANES 1999-2002 with complete data on age, current measured body weight and height, self-reported body weight 1 year ago, BMI and gender. All estimates were weighted using NHANES four-year MEC sampling weights and NHANES design corrections were applied. [2]Referent group was the fully food secure category. [3]Excluded from analysis due to inadequate sample sizes. [4]Analysis was based on current measured BMI. [†]Appreciable increase, $P < 0.06$.
*Significantly different from the fully food secure category in the same column, $p < 0.05$.

Table 7. Overweight and obesity by current measured body mass index in relation to food security status using current measured body mass index

Adult food security status[1]	n	Overweight[2] (BMI 25 – 29.9)	Obese (BMI ≥ 30)
		OR (95% CI)[3]	
Men			
Marginal food security	236	1.35 (0.87-2.1)	1.97 (1.25-3.08)*
Food insecure without hunger	288	0.68 (0.38-1.21)	0.77 (0.43-1.36)
Food insecure with hunger	162	0.83 (0.45-1.52)	0.80 (0.37-1.73)
Women			
Marginal food security	271	1.11 (0.66-1.86)	1.51 (0.92-2.51)
Food insecure without hunger	252	0.97 (0.50-1.87)	1.81 (1.12-2.93)*
Food insecure with hunger	143	2.48 (1.27-4.85)*	1.45 (0.63-3.36)

[1]Includes adults 18-50 y who participated in the NHANES 1999-2002 with non-missing data for age, current measured body weight, self-reported body weight 1 year ago, BMI and gender. NHANES 1999-2002 MEC four-year full sampling weights and design corrections were applied. [2]Analysis was based on current measured BMI. [3]Odds ratios compared with fully food secure category, 95% confidence interval in parenthesis. Logistic regression analysis controlled for age, education, ethnicity, income and smoking, *Significantly higher than the fully food secure category in the same column, $p < 0.05$.

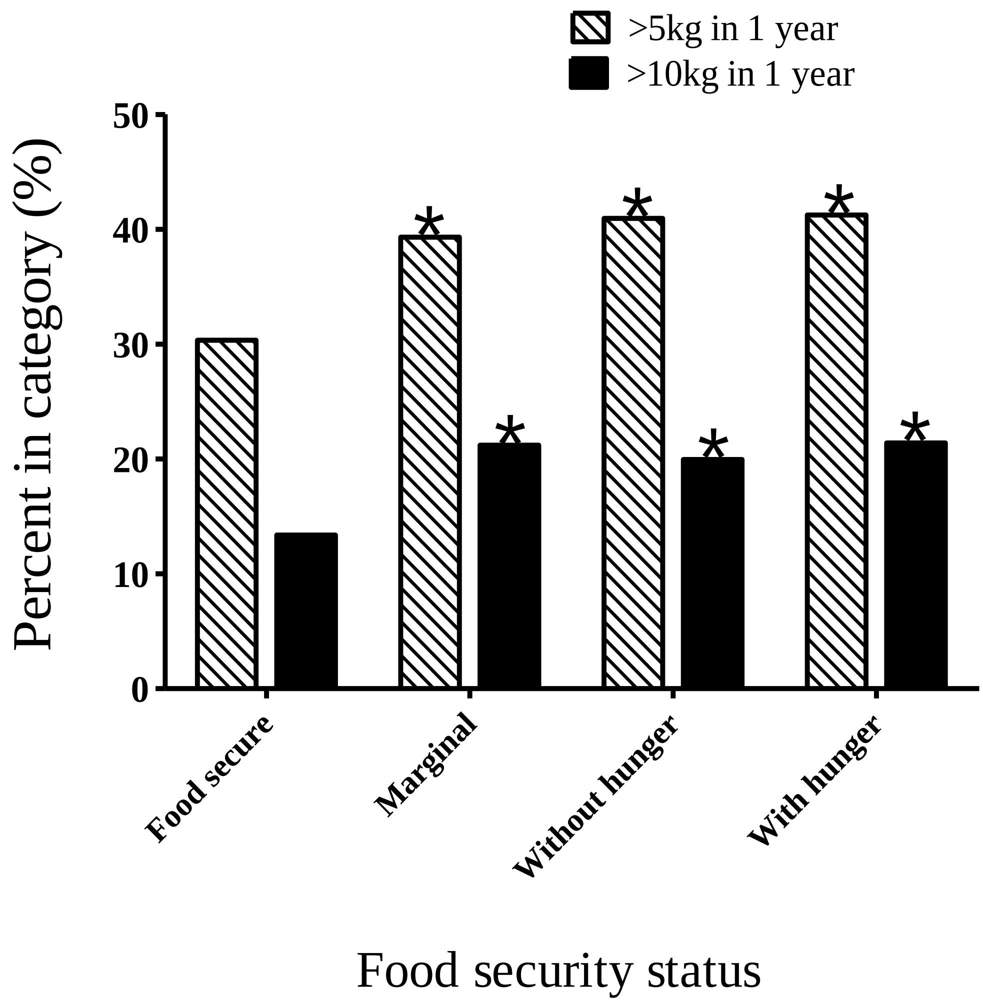

Figure 1. Prevalence of weight gain greater than 5kg and 10kg in 1 year among women by adult food security status. Weight gain was the difference between current body weight and body weight one or ten years ago, respectively. NHANES 1999-2002 MEC four-year full sampling weights and design corrections were applied. The fully food secure category was the referent group. *Significantly higher than the fully food secure category in the same category, $P < 0.05$.

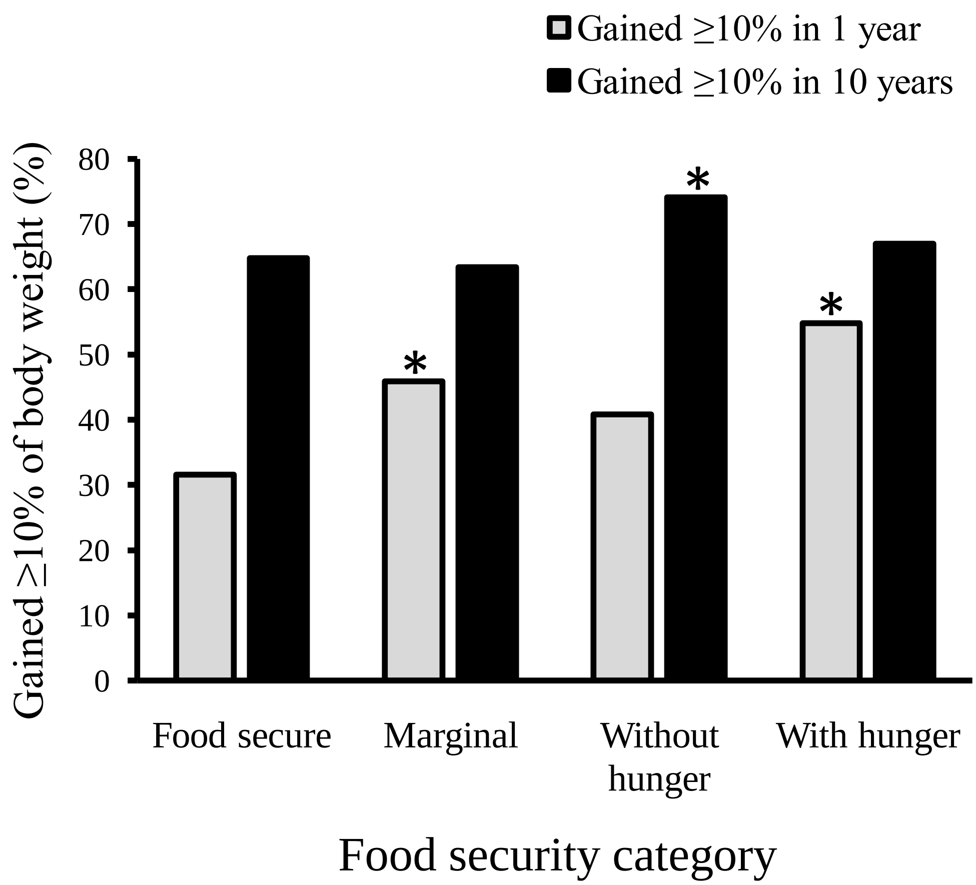

Figure 2. Weight gain greater or equal to 10 percent in one and ten years among women by food security status. Weight gain was the difference between current body weight and body weight one or ten years ago, respectively. NHANES 1999-2002 MEC four-year full sampling weights and design corrections were applied. The fully food secure category was the referent group. *Significantly higher than the fully food secure category in the same category, $p < 0.05$.

CHAPTER 5

ASSOCIATIONS BETWEEN ADULT FOOD INSECURITY AND DYSLIPIDEMIA AND ELEVATED PLASMA GLUCOSE[1]

Abstract

The objectives of this study were to estimate the likelihood of dyslipidemia and elevated plasma glucose (EPG) among food insecure persons compared with fully food secure persons. A total of 2,572 men and 2,976 women who participated in the NHANES 1999-2002 were included in this study. Gender-stratified descriptive comparisons and multiple logistic regression procedures were applied. Results of the bivariate comparisons showed that, compared with the fully food secure, significantly higher percentage of marginally food secure and food insecure without hunger women associated with dyslipidemia. The multiple regression analysis showed that, compared with fully food secure, women who were marginally food secure were more likely to associate with dyslipidemia indicated by abnormal levels of LDL-C (P = 0.045) and TG/HDL-C ratio (P = 0.046). Women who were food insecure without hunger were more likely to associate with dyslipidemia indicated by abnormal levels of TG (P = 0.041). Food insecure men and women were equally likely as their fully food secure counterparts to associate with EPG. In conclusion, marginal food security and food insecurity without hunger among

---

[1]Meanings of abbreviations: HDL-C, high-density lipoprotein cholesterol; LDL-C, low-density lipoprotein cholesterol; TG, triglycerides.

women associated with dyslipidemia. Longitudinal studies of the factors that influence associated serum components, including dietary intake and food choices are needed to further ascertain this observation.

Key Words. Cardiovascular disease, food insecurity, lipoprotein cholesterol

Introduction

Food insecurity, defined as having limited or uncertain availability of nutritionally adequate and safe food or limited or uncertain ability to acquire acceptable foods in socially acceptable ways (Bickel and others, 1999; Anderson, 1990; LSRO Expert Panel, 1989), affects about 11% of adults in the United States (USDA, 2007). Food insecure persons experience socio-economic deprivation and lack of access to resources, including lack of financial resources and inadequate access to health care (Seligman and others, 2007; Wunderlich and Norwood, 2006). Thus, many food insecure persons may not be aware of their disease condition (Seligman and others, 2007; Kushel and others, 2006).

Significant associations between food insecurity and risks of several diseases, including cardiovascular disease (CVD) and diseases predisposing to CVD, have been reported (Holben, 2004; Vozoris and Tarasuk, 2003; Dixon and others, 2001). The dominant risk factors for CVD include hypercholesterolemia, hyperglycemia, hypertension, overweight and obesity (NCEP, 2007; Patt and others, 2003; Aronne, 2002; Expert Panel, 1998). Abnormal levels of various serum lipids such as serum triglyceride (TG), total cholesterol (TC), low-density lipoprotein cholesterol (LDL-C) and high-density lipoprotein cholesterol (HDL-C) are known risk factors for CVD (NCEP, 2007).

Elevated blood glucose (EPG) is positively correlated with CVD (NCEP, 2007; Denke, 1993).

Studies on the associations between food insecurity and factors predisposing to CVD are scarce (Seligman and others, 2007). In some studies, the prevalence of CVD, type 2 diabetes and hypertension were higher among food insecure persons (Holben, 2004; Vozoris and Tarasuk, 2003). However, most of these studies were based on self-rated or self-reported disease conditions which are prone to bias. A study of the associations between food insecurity and CVD risk using objective measures such as levels of serum TG, TC, LDL-C and HDL-C (NCEP, 2007) is warranted.

Food insecurity associates with poor diet (Sharkey, 2003; Dixon, 2001, Rose, 2000) and overweight and obesity (Wilde and Peterman, 2006; Adams and others, 2003; Townsend and others, 2001) which are independent risk factors for CVD (Eckel and Krauss, 1998). Due to its associations with overweight and obesity, and poor dietary habits, it is tempting to assume that food insecurity would associate with dyslipidemia. This study estimated the likelihood of dyslipidemia and EPG among food insecure persons by examining concentrations of related plasma and serum components.

Research Methods and Procedures

Study Sample and Data Sources

The NHANES 1999-2000 and 2001-2002 (NHANES 1999-2002) laboratory data were pooled for this study. The NHANES is a nationally representative survey conducted by the National Center for Health Statistics of the Centers for Disease Control (CDC) on yearly basis though data are released in a two-year cycle (CDC, 2007a). The NHANES uses a stratified, multistage probability cluster sampling method. It is a yearly cross-sectional survey that covers the non-institutionalized civilian population of the United States (CDC, 2007a).

The study sample was obtained by applying the following inclusion criteria: age between 18-50 years, not pregnant, not lactating, health status excellent to fair, had complete information on serum total cholesterol (TC), BMI, food security status and gender. Only participants aged 18-50 years were included to obviate the complex influence of aging on blood lipids levels (NCEP, 2007; Edelstein and others, 2005; Denke, 1993). A total of 5,548 participants, comprising 2,572 men and 2,976 women qualified and were included in this study. The NHANES 1999-2002 used a sub-sample for the data collection on TGs, LDL-C and plasma glucose. For this sub-sample, 2,695 participants comprising 1,268 men and 1,427 women were included in this study.

The NHANES 1999-20002 laboratory data file provided person-level information suitable for the study of associations between food insecurity and dyslipidemia. The NHANES demographic questionnaire contained socio-demographic information including age, gender, income, race/ethnicity and level of education. Smoking status and physical activity level were obtained from the smoking status and tobacco use, and physical activity and physical fitness questionnaires, respectively. Body weight and body mass index data were from the NHANES Mobile Examination Center (MEC) body measures data files (CDC, 2007c).

NCHS Ethics Review Board approved the survey protocols and informed consent was obtained from all subjects (CDC, 2007c). The procedures for this study were approved locally by the Institutional Review Board, Office of Human Subjects Research, Auburn University.

Assigning Food Security Status

In the NHANES 1999-2002, food related circumstances over the past 12 months were used to assign adults into food security categories as fully food secure, marginal food security, food insecure without hunger and food insecure with hunger. The 10-item adult food security scale from the U.S. 18-item Food Security Survey Module (FSSM) (USDA, 2004) was used for the food security status assessment. Some of the adult items included: In the last 12 months; "did you ever eat less than you felt you should because there wasn't enough money for food?", "were you ever hungry, but didn't eat, because you couldn't afford enough food?", and "did you or other adults in your household ever not eat for a whole day because there wasn't enough money for food?" (Nord and others, 2005; Carlson and others, 1999). Participants were deemed fully food secure if they gave no affirmative response to the 10 adult items, marginal food security if they gave affirmative responses to 1-2 items, food insecure without hunger if they gave 3-5 affirmative responses and food insecure with hunger if they gave ≥6 affirmative responses (USDA, 2004). In this study, adult food security status was used because the influences of food insecurity could vary across household members (Kaiser and others, 2002; Dixon and others, 2001; Hamilton and others, 1997) and also adults are the first to adopt coping behaviors to food insecurity including limiting of the quantity and quality of foods consumed or skipping of meals (Kaiser and others, 2002).

Serum Lipids and Plasma Glucose Data

The NHANES MEC laboratory data files contained participants' information on plasma glucose, serum triglycerides, total cholesterol, high-density lipoprotein cholesterol and low-density lipoprotein cholesterol appropriate for this study (CDC, 2007e). In the NHANES MEC, plasma glucose (CDC, 2007f; CDC, 1976) and serum lipids determinations were done by enzymatic spectrophotometric methods using fasting blood samples (CDC, 2007e).

Glucose determination

The enzyme hexokinase catalyzes the reaction between glucose and adenosine triphosphate (ATP) to form glucose-6-phosphate (G-6-P) and adenosine diphosphate (ADP). In the presence of nicotinamide adenine dinucleotide (NAD), G-6-P is oxidized by the enzyme glucose-6-phosphate dehydrogenase (G-6-PD) to 6-phosphogluconate and reduced nicotinamide adenine dinucleotide (NADH). The increase in NADH concentration is directly proportional to the glucose concentration and can be measured spectrophotometrically at 340 nm (CDC, 2007f; CDC, 1976).

Serum lipids determination

Total cholesterol was measured enzymatically in serum in a series of coupled reactions that hydrolyze cholesteryl esters and oxidize the 3-OH group of cholesterol. One of the reaction byproducts, H_2O_2 is measured quantitatively in a peroxidase-catalyzed reaction that produces a red color. Absorbance is measured at 500 nm. The color intensity is proportional to cholesterol concentration (CDC, 2007e).

HDL-cholesterol was measured using a heparin-manganese precipitation method. Lipoproteins are removed by precipitation with heparin sulfate and $MnCl_2$. HDL-cholesterol is then measured in the supernatant as described above for total cholesterol. Further details of the laboratory methods and quality control procedures have been published elsewhere for public use (CDC, 2007e; CDC, 1976).

Identification of dyslipidemia and elevated plasma glucose

Reference clinical guidelines/cut-offs were used to categorize subjects into normal and at risk (or high) groups. Elevated plasma glucose (EPG) cut-offs were based on the American Diabetes Association criteria: normal, < 95; EPG, ≥ 95mg/dl (Edelstein and others, 2005). Total cholesterol (TC): normal, <240 mg/dl; high, ≥240 mg/dl (NCEP, 2007; Brown, 2000). LDL-C: normal, < 130 mg/dl; high, ≥130 mg/dl (NCEP Expert Panel, 2001). TG: normal, <150 mg/dl; high, ≥150 mg/dl (Kompoti and others, 2006; Patt and others, 2003). The cut-offs for the ratios were LDL-C/HDL-C ratio: normal, <2.5; high, ≥2.5 (Herron and others, 2002; McNamara and Min, 2002), TC/HDL-C ratio: normal, <3.5; high, ≥3.5 (Lemieux and others, 2001; Anderson and others, 1991). TG/HDL-C ratio: normal, <3.0; high, ≥3.0 (McLaughlin and others, 2003). HDL-C cutoffs were for men: normal, ≥ 40; low, < 40 mg/dl, and women: normal, ≥ 50; low, <50 mg/dl (Kompoti and others, 2006; Patt and others, 2003).

Statistical Analysis and Control Variables

In the study of the associations between food insecurity and dyslipidemia and EPG, control variables were age, level of education, income, level of physical activity, race/ethnicity and smoking status, within the limitations of available data sets (Armour, 2007; Davison, 2002; Winkleby and others, 1999). Level of education was collapsed into less than high school degree and high school degree or higher. Because sample sizes were small for some race\ethnic groups, it was collapsed into three categories: Black (non-Hispanic), Mexican-American and other Hispanics, and White (non-Hispanic). A dichotomous variable was created for income as income <185% and ≥185% of the Federal poverty threshold. Physical activity was self-reported as less than average, same as average and greater than average American. Even though self-reported physical activity is prone to respondent bias, it has been found applicable in many studies (Jones and Frongillo, 2007; van Dam and others, 2006; Neumark-Sztainer, 2003). Participants who reported use of 100 cigarettes, pipes 20 times, and cigars 20 times in their life time and currently use tobacco were classified as smokers (Funada and others, 2008). Those who reported previous smoking were classified as ex-smokers. Those who reported never smoking to all were classified as never smokers. The U.S. Census 2000 age grouping format was used (U.S. Census Bureau, 2007).

In the NHANES, full-sample and sub-sample survey weights indicating the probability of being sampled for analysis were assigned to participants. In cognizance of data release recommendations and to correct for complex NHANES design (CDC, 2007d), all estimates were weighted by using MEC four-year full-sample or sub-sample weights, where appropriate (CDC, 2007d; Alaimo and others, 2001). The NHANES 1999-2002 sub-sample weights were applied to the TG, LDL-C and plasma glucose data (CDC, 2007e; Alaimo and others, 2001) which were sub-sampled.

Statistical analyses were done using STATA 10.0 (STATA Corporation, College Station, Texas) and SAS 9.1.3 (SAS Institute Inc., Cary, NC) statistical software. To correct for MEC sampling design and to apply MEC sampling weights, STATA 10.0 (College Station, TX) was used to estimate all descriptive and inferential statistics (CDC, 2005).

Gender-stratified bivariate comparisons of proportions with dyslipidemia and EPG by food security status were performed. Significant bivariate associations were tested by using a χ^2 test followed by a two-group proportions test. Multiple logistic regression analysis was performed to estimate odds ratios (OR) for dyslipidemia in relation to food insecurity stratified by gender. The referent group for the main exposure variable, food insecurity was the fully food secure category. The referent groups for the covariates were age 18-24 year group, high school degree or higher, physical activity same as average American, never smoker and White (non-Hispanic). All variables were entered as indicator variables. Statistical significance was tested at $P < 0.05$.

Results

Sample Characteristics

Of the total of 5,548 participants, men made up 49.76% and women 50.24%. Those who were fully food secure and marginally food secure together made up 88.92% of this sample. Food insecure without and hunger men and women comprised about 11% of this sample. Additional socio-demographic characteristics of participants in this study categorized by adult food security status are shown in Table 1.

Adult Food Security Status, Dyslipidemia and Elevated Plasma Glucose

Mean serum lipids and plasma glucose concentrations stratified by gender in relation to food security status are shown in Table 2. In both men and women, the bivariate comparisons did not show significant associations between food insecurity and EPG compared with the fully food secure (Table 3). Compared with the fully food secure, food insecurity among men did not associated with dyslipidemia. A higher proportion of marginally food secure women associated with dyslipidemia through abnormal levels of HDL-C, and TC/HDL-C and TG/HDL-C ratios (Figure 1). In addition, a higher proportion of food insecurity without hunger women associated with abnormal levels of TG and values of TC/HDL-C and TG/HDL-C ratios. Results of the multiple logistic regression analysis showed that, compared with fully food secure, women who were marginally food secure were more likely to associate with abnormal levels of LDL-C ($P = 0.045$) and TG/HDL-C ratio ($P = 0.046$) (Table 4). Women who were food insecure without hunger were more likely to associate with abnormal levels of TG ($P = 0.041$) (Figure 2).

Discussion

A significant finding in this study is that marginal food security and food insecurity without hunger (i.e., intermediate-level food insecurity) among women associated with dyslipidemia. Intermediate-level food insecure women were more likely to have dyslipidemia as indicated by abnormal levels of TG, LDL-C and TG/HDL-C ratios. The results of this study is in agreement with that of Dixon and other (2001) who earlier observed that food insecure persons associate with significantly higher levels serum TC.

The use of multiple serum and plasma indicators associated with dyslipidemia in the present study adds further impetus to this association.

The associations between intermediate-level food insecurity and dyslipidemia may predispose such individuals to CVD. Large population-based prospective studies have demonstrated that dyslipidemia including high levels of serum TG, TC, LDL-C and low levels of HDL-C are positively correlated with CVD (NCEP, 2007; Edelstein and others, 2005; Denke, 1993). Food insecurity may associate with dyslipidemia through its associations with poor dietary intake and overweight and obesity. Food insecurity associates with poor dietary intake (Gulliford, 2005; Sharkey, 2003; Dixon, 2001, Rose, 2000) which influences levels of serum lipoproteins (Greene and others, 2006; Gardner and others, 2005, Stefanick and others, 1998). Among the food insecure, there are decreases in the intakes of antioxidant nutrients which are protective against peroxidation of plasma lipids and hence against CVD (Kirkpatrick and Tarasuk, 2008; Hromi-Fiedler and others, 2007; Lee and Frongillo, 2001).

Several studies report significant associations between intermediate-level food insecurity among women and overweight and obesity (Adams and others, 2003; Townsend and others, 2001; Dietz, 1995). However, overweight and obesity are independent risk factors for CVD, mortality from CHD and all-cause mortality (Gensini and others, 1998; Rexrode and others, 1998; Pi-Sunyer, 1993). The link between overweight and obesity and CVD risk is partly through its associations with traditional CVD risk factors including elevated levels of TC, LDL-C and hyperglycemia and depressed levels of HDL-C (NCEP, 2007; Edelstein and others, 2005; Gensini and others, 1998). It is likely that the widely reported association between intermediate-level food insecurity and overweight and obesity among women also raises their risk for CVD.

The strengths of our study lie in the fact that this analysis accounted for important covariates including smoking status which is common among food insecure persons and may influence their dietary habits (Troisi and others, 1991; Klesges and others, 1990), body weight (Lissner and others, 1992; Manson, 1987) and serum lipid levels (Thun, 2005; AHA, 2004; NHLBI Expert Panel, 2000). Another important strength is that food security data covered a reference period of 12 months to improve sensitivity and to provide a more reliable assessment. In addition, this study included a large sample of persons in the United States and that the conduct of the study was carefully standardized (USDA, 2007).

One limitation of this study is that the relationships between food insecurity and dyslipidemia and EPG were based on cross-sectional data which do not permit causal inferences (Wilde and Peterman, 2006; Olson, 1999). However, the observed associations between food insecurity and dyslipidemia strengthen the growing evidence that food insecurity contributes to poor health in this population.

The results of the present study show food insecurity may have more serious consequences, because dyslipidemia is an important factor in the development of CVD which is one of the major causes of morbidity and mortality in developed countries (NCEP, 2007; AHA, 2004; Gensini and others, 1998). It appears more important because about 11% of this population is food insecure. Alleviation of food insecurity, especially among women, would contribute immensely to ameliorate the incidence of CVD and related public health problems and improve wellbeing.

In conclusion, marginal food security and food insecurity without hunger among women associated with dyslipidemia. Longitudinal studies of the factors that influence levels of serum components associated with dyslipidemia, including dietary intake and food choices are needed to further ascertain this observation.

Table 1. Background characteristics of participants by adult food security status

Characteristic[1,2]	Fully food secure (n = 4,120)	Marginal food security (n= 541)	Food insecure without hunger (n = 572)	Food insecure with hunger (n = 315)	Sample Total (n= 5,548)
			Mean ± SE		
BMI (kg/m^2)					
Men	27.40 ± 0.16	28.73 ± 0.65	25.89 ± 0.49	27.10 ± 0.70	27.37 ± 0.16
Women	27.50 ± 0.24	29.21 ± 0.44	29.39 ± 0.87	28.53 ± 0.88	27.79 ± 0.22
			Percent (%)		
Age group[3]					
18-24	18.96	24.85	26.44	27.13	20.22
25-34	27.35	35.31	31.61	27.54	28.18
35-44	34.38	24.28	29.01	31.38	33.21
45-50	19.31	15.56	12.94	13.95	18.40
Gender					
Men	49.95	54.50	50.19	49.28	50.24
Women	50.05	45.50	49.81	50.72	49.76
Ethnicity					
White (Non-Hisp)	76.45	44.80	48.58	60.43	71.77
Black (Non-Hisp)	10.13	21.14	16.91	14.25	11.51
Mexican Amer[4]	13.41	34.06	34.51	25.32	16.73
Education					
< High school	41.17	65.60	65.72	70.17	45.73
≥ High school	58.83	34.40	34.28	29.83	54.27
Income					
< 185%	27.07	69.86	77.42	82.28	35.55
≥ 185%	72.93	30.14	22.58	17.72	64.45
Smoking					
Never-smoker	53.01	51.36	45.13	33.77	51.52
Ex-smoker	19.25	12.59	15.34	13.37	18.29
Current smoker	27.73	36.05	39.53	52.86	30.19

[1]All estimates were weighted and design corrections were applied using NHANES 1999-2002 four-year MEC sampling weights and design corrections.

[2]Includes adults 18-50 years who participated in the NHANES 1999-2002 with data on age, BMI, blood glucose and lipids, and gender.

[3]The U.S. Census 2000 age grouping format was used (U.S. Census Bureau, 2007).

[4]Includes other Hispanics.

Table 2. Serum lipids and plasma glucose concentrations of men and women by food security status

Component	n	Fully food secure	n	Marginal food security	n	Food insecure without hunger	n	Food insecure with hunger
				Mean ± SE[1,2]				
Glucose								
Men	948	99.44 ± 1.02	105	97.73 ± 2.10	144	101.29 ± 6.52	71	105.99 ± 5.97
Women	1,081	92.61 ± 0.66	135	91.95 ± 2.05	147	98.05 ± 3.04	64	94.44 ± 2.73
Triglycerides								
Men	948	157.99 ± 7.47	105	137.68 ± 13.55	144	148.95 ± 16.98	71	146.08 ± 5.97
Women	1,081	114.51 ± 3.54	135	118.65 ± 9.43	147	138.75 ± 16.13	64	135.80 ± 20.89
Total cholesterol								
Men	1,897	198.41 ± 1.76	234	193.03 ± 3.69	278	193.91 ± 4.86	163	190.55 ± 3.61
Women	2,223	192.73 ± 0.91	307	188.31 ± 3.10	294	196.26 ± 3.67	152	199.31 ± 4.17
HDL cholesterol								
Men	1,897	45.35 ± 0.57	234	43.84 ± 1.10	278	45.99 ± 0.88	163	47.79 ± 1.41
Women	2,223	55.03 ± 0.59	307	51.87 ± 1.19	294	53.07 ± 1.26	152	52.26 ± 1.86
LDL cholesterol								
Men	948	123.47 ± 1.53	105	116.55 ± 3.13	144	115.39 ± 3.63	71	121.74 ± 6.60
Women	1,081	113.88 ± 1.36	135	112.49 ± 3.71	147	117.73 ± 5.16	64	111.80 ± 4.47
TC/HDL ratio[3]								
Men	1,897	4.69 ± 0.05	234	4.73 ± 0.18	278	4.46 ± 0.15	163	4.36 ± 0.11
Women	2,223	3.75 ± 0.05	307	3.80 ± 0.08	294	4.00 ± 0.13	152	4.10 ± 0.18

[1]All estimates were weighted using NHANES four-year MEC sampling weights, NHANES 1999-2002 design corrections were applied. [2]Includes adults 18-50 years who participated in the NHANES 1999-2002 with complete data on age, BMI, plasma glucose, serum lipids and gender.
[3]Total cholesterol to HDL cholesterol ratio.

Table 3. Prevalence of dyslipidemia and elevated plasma glucose among men and women in relation to adult food security status

Indicators[1,2]	Fully food secure[3]	Marginal food security	Food insecure without hunger	Food insecure with hunger
	Percent (%)			
EPG[4]				
Men	55.22	45.76	47.15	52.40
Women	29.12	27.98	35.36	35.54
Triglycerides				
Men	34.96	24.90	32.30	33.86
Women	21.39	23.23	31.33**	22.43
Total cholesterol				
Men	15.57	13.18	15.85	9.68
Women	11.57	10.41	15.09	13.37
HDL-cholesterol				
Men	37.49	43.98	35.76	38.29
Women	41.90	51.29*	44.21	47.22
LDL-cholesterol				
Men	40.62	35.08	37.68	44.54
Women	27.29	29.93	35.02	30.09
LDL/HDL-C ratio				
Men	65.57	61.06	58.77	60.81
Women	35.20	34.30	40.69	34.87
TC/HDL ratio				
Men	77.61	78.83	73.24	72.61
Women	51.76	59.24*	59.77**	56.43
TG/HDL ratio				
Men	47.23	42.88	42.11	50.31
Women	23.83	37.37**	33.97*	33.70

[1]Includes adults 18-50 years who participated in the NHANES 1999-2002 with complete data on age, BMI, plasma glucose, serum lipids and gender. [2]All estimates were weighted using NHANES four-year MEC sampling weights, survey design corrections were applied. [3]Reference group. [4]Elevated plasma glucose (EPG) cut-off was based on ADA criteria: normal, < 95; high, ≥ 95mg/dl (ADA, 1997). LDL cholesterol: normal, < 130 mg/dl; high, ≥130 mg/dl (NCEP Expert Panel, 2001). LDL/HDL ratio cut-off: Normal, <2.5; high, ≥2.5 (Herron and others, 2002; McNamara and Min, 2002). Total cholesterol: normal, < 240 mg/dl; high, ≥240 mg/dl (NCEP, 2007). Total cholesterol/HDL ratio: normal, <3.5; high, ≥3.5 (Lemieux and others, 2001; Anderson and others, 1991). Triglycerides/HDL ratio: normal, <3.0; high, ≥3.0 (McLaughlin and others, 2003). Triglycerides cut-offs: normal, <150; high, ≥150 (Kompoti and others, 2006; Patt and others, 2003). HDL cholesterol cutoffs: Males - normal, ≥ 40; low, < 40 mg/dl. Females - normal, ≥ 50; low, <50 mg/dl (Kompoti and others, 2006; Patt and others, 2003). **Significantly higher than the fully food secure group, $p < 0.05$. *Statistically higher than the fully food secure group, $P < 0.10$.

Table 4. Dyslipidemia and elevated plasma glucose among food insecure men and women

Indicators[1]	Marginal food security	Food insecure without hunger	Food insecure with hunger
	OR (95% CI) compared with fully food secure category[2,3]		
Men[4]			
EPG	0.50 (0.28-1.02)	0.53 (0.25-1.10)	0.69 (0.26-1.82)
Triglycerides	0.59 (0.29-1.23)	1.00 (0.45-2.21)	0.77 (0.35-1.70)
Total cholesterol	0.98 (0.48-2.02)	1.37 (0.74-2.53)	0.76 (0.39-1.55)
HDL-cholesterol	1.23 (0.75-2.03)	1.07 (0.71-1.61)	0.78 (0.43-1.42)
LDL-cholesterol	1.23 (0.75-2.03)	1.07 (0.71-1.61)	1.23 (0.53-2.28)
LDL/HDL-C ratio	0.93 (0.59-1.48)	0.66 (0.31-1.43)	0.74 (0.32-1.73)
TC/HDL ratio	1.19 (0.67-2.14)	0.82 (0.46-1.49)	0.58 (0.29-1.14)
TG/HDL ratio	0.84 (0.46-1.53)	0.92 (0.43-1.96)	0.91 (0.43-1.93)
Women[4]			
EPG	1.08 (0.54-2.19)	1.10 (0.59-2.05)	1.38 (0.47-4.01)
Triglycerides	1.09 (0.46-2.62)	1.90 (1.02-3.56)*	1.00 (0.38-2.42)
Total cholesterol	0.92 (0.42-1.97)	1.13 (0.55-2.33)	1.02 (0.49-2.16)
HDL-cholesterol	1.02 (0.59-1.76)	0.78 (0.49-1.24)	0.72 (0.34-1.56)
LDL-cholesterol	1.85 (1.06-3.23)*	1.52 (0.83-2.81)	0.78 (0.28-2.19)
LDL/HDL-C ratio	0.93 (0.52-1.65)	0.95 (0.47-1.94)	0.43 (0.11-1.60)
TC/HDL ratio	1.22 (0.80-1.86)	0.96 (0.59-1.57)	0.78 (0.40-1.52)
TG/HDL ratio	1.91 (1.08-4.60)*	1.41 (0.70-2.84)	1.12 (0.41-3.07)

[1]Includes men and women 18-50 years who participated in the NHANES 1999-2002 with complete data on age, BMI, plasma glucose, serum lipids and gender. [2]All estimates were weighted using NHANES four-year MEC sampling weights, survey design corrections were applied. [3]Multiple logistic regression analysis controlled for age, education, ethnicity, income, level of physical activity and smoking. [4]See Table 3 for reference cut-offs for the serum lipids. *Likelihood of abnormal concentration is significantly higher than the fully food secure group, $p < 0.05$.

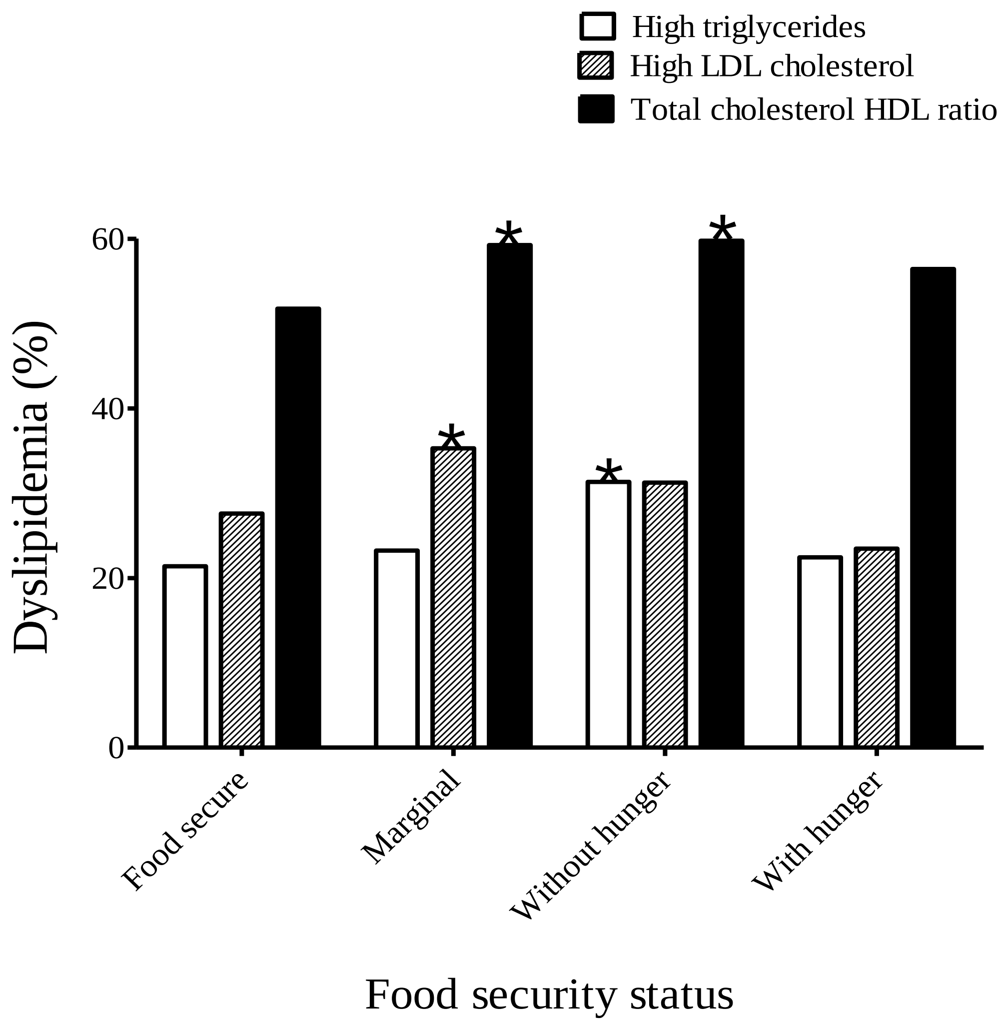

Figure 1. Prevalence of dyslipidemia among women in relation to food security status. Include adults 18-50 years who participated in the NHANES 1999-2002 with data on age, BMI, plasma glucose, serum lipids and gender. All estimates were weighted using NHANES 1999-2002 four-year MEC sampling weights. NHANES 1999-2002 Survey design corrections were applied. Triglycerides cut-offs: normal, <150; high, ≥150 (Kompoti and others, 2006; Patt and others, 2003). LDL cholesterol: normal, < 130 mg/dl; high, ≥130 mg/dl (NCEP Expert Panel, 2001). Total cholesterol/HDL ratio: normal, <3.5; high, ≥3.5 (Lemieux and others, 2001; Anderson and others, 1991). The fully food secure category was the referent group. *Significantly higher than the fully food secure category, $p < 0.05$.

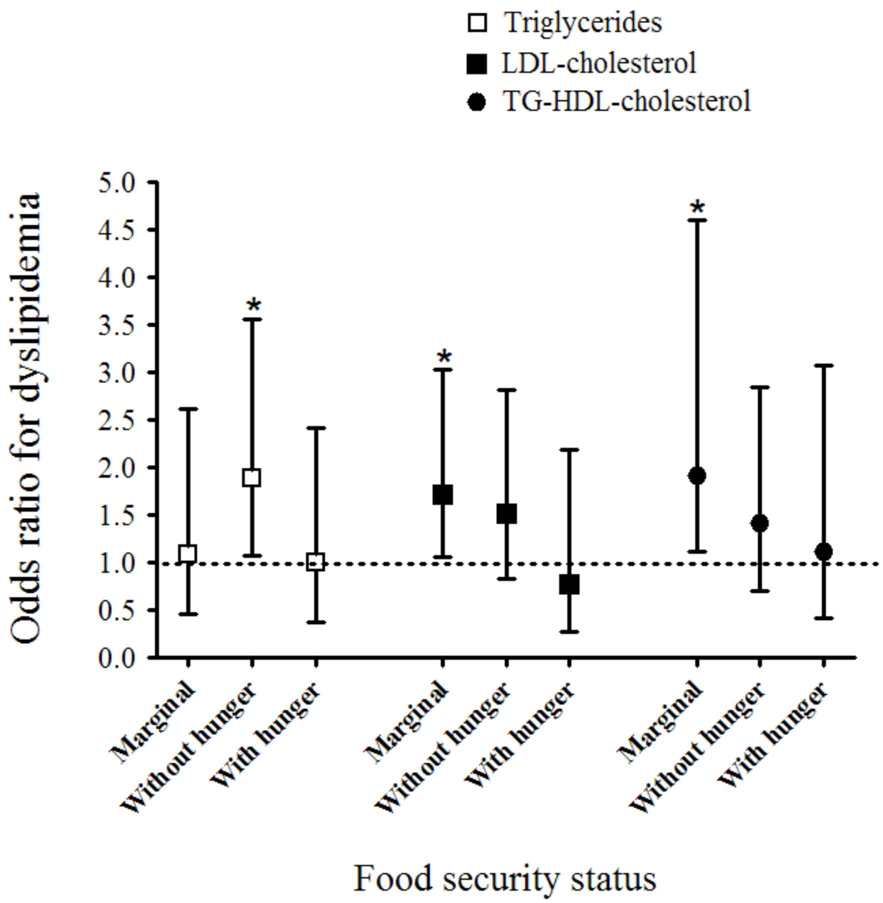

Figure 2. Dyslipidemia among women in relation to food security status. Include adults 18-50 years who participated in the NHANES 1999-2002 with data on age, BMI, blood glucose and lipids, and gender. All estimates were weighted using NHANES 1999-2002 four-year MEC sampling weights. NHANES 1999-2002 Survey design corrections were applied. Triglycerides cut-offs: normal, <150; high, ≥150 (Kompoti and others, 2006; Patt and others, 2003). LDL cholesterol: normal, < 130 mg/dl; high, ≥130 mg/dl (NCEP Expert Panel, 2001). Total cholesterol/HDL ratio: normal, <3.5; high, ≥3.5 (Lemieux and others, 2001; Anderson and others, 1991). The fully food secure category was the referent group. *Significantly higher than the fully food secure group, $p < 0.05$.

CHAPTER 6

OVERALL CONCLUSIONS

The influence of food insecurity among this population appears to go beyond just contextual associations with overweight and obesity. Among men, severe food insecurity associates with decreases in height, percent body fat and BMI whereas marginal food security associates with greater weight gain. Among women, intermediate-level food insecurity associates with decreased height, increased BMI, greater weight gain during 1 and 10 years, and dyslipidemia. Stratifying by height identified below median height marginally food secure women as more prone to increases in BMI. Unlike men, food insecurity among women did not associate with percent body fat. Food insecurity among women associates with significant weight gain at both the >5kg and >10kg specifications and during both 1 and 10 years.

The associations between food insecurity and increased body weight, decreased height, and dyslipidemia among women, highlight the need for more vigorous public health efforts to alleviate the effects of food insecurity and to improve food security both in the short and long term in this population. Food insecurity associates with dyslipidemia and weight gain all of which are known risk factors of CVD. Thus, alleviation of food insecurity, especially among women, would contribute immensely to ameliorate the incidence of CVD and related public health problems. Food insecure individuals may be more prone to overweight and obesity, shorter adult height and dyslipidemia.

Further work should focus on longitudinal studies of food insecurity, its transitions and timing in life, and related coping behaviors. Such studies should include repeated measures of dietary intake, food choices and consumption patterns, height, body weight and adiposity over a broad range of the life cycle of food insecure persons to elucidate such associations.

REFERENCES

Adams EJ, Grummer-Strawn L, Chavez G. Food insecurity is associated with increased risk of obesity in California women. J Nutr. 2003;133:1070-4.

Alaimo K, Olson CM and Frongillo EA. Food insufficiency and american school-aged children’s cognitive, academic, and psychosocial development. Pediatrics. 2001;108:44-53.

Alaimo K, Olson CM, Frongillo EA. Low family income and food insufficiency in relation to overweight in US children. Arch Pediatr Adolesc Med. 2001b;155:1161-1167.

Alaimo K., and Froelich, A. Alternative construction of a food security and hunger measure from 1995 Current Population Survey Food Security Supplement data. Paper presented at the Workshop on the Measurement of Food Insecurity and Hunger, July 15, 2004. Available at http://www7.nationalacademies.org/cnstat/Alternative_Construction of_Food_Security_Paper.pdf. Accessed December 9, 2006.

Ali SM and Lindstrom M. Socioeconomic, psychosocial, behavioral, and psychological determinants of BMI among young women: differing patterns for underweight and overweight/obesity. European Journal of Public Health. 2005;16(3):324-330.

Allebeck P, Bergh C. Height, body mass index and mortality: do social factors explain the association? Public Health. 1992 Sep;106(5):375-82.

American Diabetes Association (ADA): Report of the Expert Committee on the Diagnosis and Classification of Diabetes Mellitus, Diabetes Care. 1997:20;1183-1107

American Heart Association (AHA). Clinical implications of obesity with specific focus on cardiovascular disease: A statement for professionals from the American Heart Association council on nutrition, physical activity, and metabolism: Endorsed by the American College of Cardiology Foundation. Circulation, 2004;110;2952-2967.

Anderson SA. Core indicators of nutritional state for difficult-to-sample populations. J Nutr, 1990;120:1557-1600.

Andersson SO, Wolk A, Bergstrom R, Adami HO, Engholm G, Englund A, Nyren O. Body size and prostate cancer: a 20-year follow-up study among 135006 Swedish construction workers. J Natl Cancer Inst. 1997 Mar 5;89(5):385-9.

Anderson KM, Wilson PW, Odell PM. An updated coronary risk profile: a statement for health professionals. *Circulation*. 1991;83:356-362.

Andrews MS, Bickel G, Carlson S. Household food security in the United States in 1995: Results from the food security measurement project. Fam Econs Nutr Rev, 1998;11(1&2):17-28.

Armour BS, Pitts MM, Lee C-W. Cigarette smoking and food insecurity among low-income families in the United States, 2001. Working Paper 2007-19. Federal Reserve Bank of Atlanta, 2007.

Aronne LJ, and Segal KR. Adiposity and fat distribution outcome measures: Assessment and clinical implications. Obesity Research. 2002 Nov; 10(Suppl. 1):14S-21S.

Bagust A and Walley T. Alternative for body mass index for standardizing body weight for stature. QJ Meds, 2000;93:589-596.

Barker DJ. Fetal nutrition and cardiovascular disease in later life. Br Med Bull, 1997;53:96-108.

Basiotis PP, Lino M. Food insufficiency and prevalence of overweight among adult women. Fam Econs and Nutr Rev, 2003;15(2):55-57.

Bendixen H, Holst C, Sørensen TIA, Raben A, Bartels EM and Astrup A. Major increase in prevalence of overweight and obesity between 1987 and 2001 among Danish adults. Obesity Research. 2004;12(9):1464-1472.

Benefice E, Garnier D, Simondon KB and Malina RM. Relationship between stunting in infancy and growth and fat distribution during adolescence in Senegalese girls. Eur J Clin Nutr. 2001; 55:50-58.

Bickel G, Nord M, Price C, Hamilton WL, Cook J. Guide to measuring household food security. Alexandria (VA): USDA, Food and Nutrition Service, Office of Analysis, Nutrition and Evaluation, 2000.

Bickel GW, Carlson S, Nord M. Household food security in the United States 1995-1998: Advance Report. Office of Analysis, Food and Nutrition Service, U.S. Department of Agriculture, Alexandria, VA, 1999.

Black MM, Cutts DB, Frank DA, et al. Special supplemental nutrition program for women, infants, and children participation and infants' growth and health: a multisite surveillance study. Pediatrics. 2004;114(1):169-76.

Blumberg SJ, Bialostosky K, Hamilton WL, Briefel RR. The effectiveness of a short form of the household food security scale. Am J Public Health. 1999; 89:1231-1234.

Bolanowski M,Nilsson BE. Assessment of human body composition using dual-energy x-ray absorptiometry and bioelectrical impedance analysis. Med Sci Monit. 2001;7(5):1029-1033.

Bray GA and Bouchard C. Genetics of human obesity: research directions. Obesity Research. 1997;11:937-945.

Bray GA. Health hazards of obesity. Endocrinol Metab Clin North Am, 1996;25:907-19.

Bray GA. What is the ideal body weight? J Nutr Biochem, 1998;9:489-492.

Briefel R, Woteki C. Development of the food insufficiency questions for the third national health and nutrition examination survey. J Nutr Educ, 1992;24(1):24S-28S.

Brown G, Albers JJ, Fisher LD, Schaefer SM, Lin JT, Kaplan C, et al. Regression of coronary artery disease as a result of intensive lipid-lowering therapy in men with high levels of apoliprotein B. N Engl J Med. 1990; 323:1289-98.

Carlson SJ, Andrews MS and Bickel GW. Measuring food insecurity and hunger in the United States: Development of a national benchmark measure and prevalence estimates. J Nutr, 1999;129: 510S-516S.

Cavelaars AEJM, Kunst AE, Geurts JJM, Criales R, Grötvedt L, Helmert U, Lahelma E, Lundberg O, Mielck A, Rasmussen NKR, Regidor E, Spuhler T, Mackenbach JP. Persistent variations in average height between countries and between socio-economic groups: an overview of 10 European countries. Ann Human Biol, 2000;27(4):407-421.

Centers for Disease Control and Prevention (CDC). National Health and Nutrition Examination Survey Data. Hyattsville, MD: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, 2005. Available at: http://thecommunity guide.org/nchs/data/nhanes/nhanes_03_04/nhanes_analytic_ guidelines_dec_2005.pdf. Accessed October 12, 2007.

Centers for Disease Control and Prevention (CDC). National Health and Nutrition Examination Survey Data. Hyattsville, MD: U.S. Department of Health and Human Services. Centers for Disease Control and Prevention, 2007c. Anthropometric procedures manual. Available at: http://www.cdc.gov/nchs/data/nhanes/bm.pdf. Accessed June 5, 2007.

Centers for Disease Control and Prevention (CDC). National Health and Nutrition Examination Survey Data. Hyattsville, MD: U.S. Department of Health and Human Services. Centers for Disease Control and Prevention, 2007d. NHANES analytical guide. Available at: http://www.cdc.gov/nchs/data/nhanes/nhanes_general_ guidelines_june_04.pdf. Accessed June 5, 2007.

Centers for Disease Control and Prevention (CDC). National Health and Nutrition Examination Survey Data. Hyattsville, MD: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, 2007e. Laboratory procedure manual for serum lipids. Available at: http://www.cdc.gov/nchs/ data/nhanes/frequency/lab13_ met_ lipids.pdf. Accessed August 7, 2007.

Centers for Disease Control and Prevention (CDC). National Center for Health Statistics (NCHS). National Health and Nutrition Examination Survey Data. Hyattsville, MD: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, 2007f. Laboratory procedure manual for plasma glucose. Available at: http://www.cdc.gov/nchs/data/nhanes/ frequency/lab25_met_ complete_blood_count.pdf. Accessed August 7, 2007.

Centers for Disease Control and Prevention. National Center for Health Statistics (NCHS). National Health and Nutrition Examination Survey Data. Hyattsville, MD: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, 2007a. Available at: http://www.cdc.gov/nchs/about/major/nhanes/ nhanes01-02.htm. Accessed May 7, 2007.

Centers for Disease Control and Prevention (CDC). National Center for Health Statistics (NCHS). National Health and Nutrition Examination Survey Data. Hyattsville, MD: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, 2006. Documentation for weight history questionnaire (WHQ) for 2001-2002 data. Available at: www.cdc.gov/nchs/ nhanes.htm. Accessed March 8, 2006.

Centers for Disease Control. A proposed method for determining glucose using hexokinase and glucose-6-phosphate dehydrogenase. Atlanta: Centers for Disease Control, 1976.

Cook JT, Frank DA, Levenson SM, Neault NB, Heeren TC, Black MM, Berkowitz C, Casey PH, Meyers AF, Cutts DB, Chilton M. Child food insecurity increases risks posed by household food insecurity to young children's health. J Nutr. 136:1073-1076, 2006.

Cook JT, Frank DF, Berkowitz C, Black MM, Casey PH, Cutts DB, Meyers AF, Zaldivar N, Skalicky A, Levenson S, Heeren T and Nord M. Food insecurity is associated with adverse health outcomes among human infants and toddlers. J Nutr, 2004;134:1432-1438.

Cristofar, SP and Basiotis, PP. Dietary intakes and selected characteristics of women ages 19-50 years and their children ages 1-5 years by reported perception of food sufficiency. J Nutr. Educ. 1992;24:53-58.

Davison KK, Ford ES, Cogswell ME, Dietz, 2002. Percentage of body fat and body mass index are associated with mobility limitations in people aged 70 and older from NHANES III. J Amer Geriatric Soc. 2002;50:1802-1809.

Denke MA, Sempos CT, Grundy SM. Excess body weight. An under-recognized contributor to high blood cholesterol levels in White American men. Arch Intern Med. 1993;153:1093-103.

Deurenberg P, Yap M, van Staveren WA. Body mass index and percent body fat: a meta analysis among different ethnic groups. Int J Obes Related Metab Disord. 1998;22(12):1164-71.

Deurenberg P. Limitations of the bioelectrical impedance method for the assessment of body fat in severe obesity. Am J Clin Nutr. 1996; 64:449S-452S.

Dietz WH. Periods of risk in childhood for the development of adult obesity: what do we need to learn? J Nutr. 1997;127:1884S-1886S.

Dietz, W. H. Does hunger cause obesity? Pediatrics, 1995;95:766-767.

Dixon LB, Winkleby MA and Radimer KL. Dietary intakes and serum nutrients differ between adults from food-insufficient and food-sufficient families: Third National Health and Nutrition Examination Survey, 1988-1994. J.Nutr, 2001;131:1232-1246.

Drewnowski A, and Specter SE. Poverty and obesity: the role of energy density and energy costs. Am J. Clin. Nutr, 2004;79:6-16.

Dulloo AG, Girardier L. Adaptive role of energy expenditure in modulating body fat and protein deposition catch-up growth after early undernutrition. Am J Clin Nutr, 1993;58:614-621.

Eckel RH, Krauss RM. American Heart Association call to action: obesity as a major risk factor for coronary heart disease. AHA Nutrition Committee. Circulation. 1998;97:2099-100.

Edelstein SL, Brancati FL, Barrett-Connor E, Engelgau MM, Hamman RF, Knowler WC, Matulik MJ and Metzger BE. Strategies to identify adults at high risk for type 2 diabetes. The Diabetes Prevention Program. Diabetes Care, 2005:28:150-156.

Eisinger, P. Toward an end to hunger in America. Washington, DC: Brookings Institution Press, 1998.

El-Bastawissi AY, Peters R, Sasseen K, Bell T, Manolopoulos R. Effect of the washington special supplemental nutrition program for women, infants and children (WIC) on pregnancy outcomes. J Matern Child Health. June 12, 2007. Available at: www.springerlink.com/ content/ r8672034916474q2/. Accessed September 16, 2007.

Expert Panel. Clinical guidelines on the identification, evaluation, and treatment of overweight and obesity in adults - the evidence report. Obesity Research. 1998;6:51-63.

Federal Register. Ten year plan for the National Nutrition Monitoring and Related Research Program. Part II. Washington, DC: U.S. Department of Health and Human Services and U.S. Department of Agriculture, 1993;58:32752-32806.

Flegal KM. Is an inverted weight-height index a better index of fatness? Obesity Research. 1997 Nov;5(suppl 1):93S.

Fontaine, KR. Years of life lost due to obesity. JAMA, 2003; 289(2):187-93. Frisard MI, Greenway FL, DeLany JP. Comparison of methods to assess body composition changes during a period of weight loss. Obesity Research. 2005;13(5):845-854.

Frongillo E, Rauschenbach B, Olson C, Kendall A, Colmenares A. Questionnaire-based measures are valid for the identification of rural households with hunger and food insecurity. J Nutr, 1997b;127:699-705.

Frongillo EA, Horan CM. Hunger, food insecurity and aging. Generations, 2004;28(3):62-63.

Frongillo EA, Olson CM. Rauschenbach BA and Kendall A. Nutritional consequences of food insecurity in a rural New York State county. Institute for Research on Poverty. University of Wisconsin, Madison. Discussion paper No. 1120-97, 1997.

Frongillo EA. Validation of measures of food insecurity and hunger. J Nutr. 1999;129:506S-9S.

Frongillo, E. A., Jr., M. de Onis, and K. M. Hanson. Socioeconomic and Demographic Factors are Associated with Worldwide Patterns of Stunting and Wasting of Children. J Nutr. 1999; 127:2302-2309.

Funada S, Schmazu T, Kakizaki M, Kuriyama S, Sato Y, Matsuda-Ohmori K, Nishino Y Tsuji I. Body mass index and cardiovascular disease mortality in Japan: The Ohsaki Study. Preventive Medicine, 2008;47:66-70.

Gardner CD, Coulston A, Chatterjee L, Rigby A, Spiller G, Farquhar JW. The Effect of a Plant-Based Diet on Plasma Lipids in Hypercholesterolemic Adults. A randomized trial. Ann Intern Med. 2005;142:725-733.

Gensini GF, Comeglio M, Colella A. Classical risk factors and emerging elements in the risk profile for coronary artery disease. Eur Heart J. 1998;19(Suppl A):A53-A61.

Giovannucci E, Rimm EB, Stampfer MJ, Colditz GA, Willett WC. Height, Body Weight, and Risk of Prostate Cancer. Cancer Epidemiology, Biomarkers and Prevention. 1997;6:557-563.

Goldbourt U, Tanne D. Body height is associated with decreased long-term stroke but not coronary heart disease mortality? Stroke, 2002;33:743-748.

Greene CM, Waters D, Clark RM, Contois JH and Fernandez ML. Plasma LDL and HDL characteristics and carotenoid content are positively influenced by egg consumption in an elderly population. Nutrition & Metabolism 2006, 3:6. Accessed, July 26, 2007 from: http://www.nutritionandmetabolism.com/ content/3/1/6.

Gulliford MC, Mahabir D Rocke B. Food insecurity, food choices, and body mass index in adults: nutrition transition in Trinidad and Tobago. Int J Epidemiol. 2003;32:508-516.

Gulliford MC, Mahabir D, Nunes C and Rocke B. Self-administration of a food security scale by adolescents: item functioning, socio-economic position and food intakes. Public Health Nutrition. 2005;8(7):853-860.

Gulliford MC, Nunes C and Rocke B. Food insecurity, weight control practices and body mass index. Public Health Nutrition. 2006a;9(5):570-574.

Gulliford MC, Nunes C and Rocke B. The 18 household food security survey items provide valid food security classifications for adults and children in the Caribbean. BMC Public Health, 2006b;6:26.

Habicht J-P, Pelto G, Frongillo E, Rose D. Conceptualization and instrumentation of food insecurity. Paper prepared for National Academy of Sciences workshop, 15-16 July, 2004.

Hakeem R. Socio-economic differences in height and body mass index of children and adults living in urban areas of Karachi, Pakistan. Eur J Clin Nutr. 2001;55:400-406.

Hamelin AM, Habicht, J-P, and Beaudry M. Food insecurity: Consequences for the household and broader social implications. J. Nutr, 1999;129:525-528.

Hamilton W, Cook J, Thompson W, Buron L, Frongillo E, Olson C, and Wehler C. Household Food Security in the United States in 1995: Technical Report of the Food Security Measurement Project. Alexandria, VA: USDA, Food and Consumer Service, Office of Analysis and Evaluation, 1997.

Hampton T. Food insecurity harms health, well-being of millions in the United States. JAMA, 2007;298(16):1851-1853.

Hanson KL, Sobal J, Frongillo EA. Gender and marital status clarify associations between food insecurity and body weight. J Nutr. 2007;137:1460-1465.

Health Canada. A community health survey of income-related household food security in Canada 2004. Office of Nutrition Policy and Promotion. Health Products and Food Branch. Accessed December 2007 from: www.hc-sc.gc.ca/fn-an/surveill/nutrition/commun/ index_e.html.

Herron KL, Vega-Lopez, S, Conde K. Pre-menopausal women, classified as hypo- or hyper-responders, do not alter their LDL/HDL ratio following a high dietary cholesterol challenge. J Am Coll Nutr. 2002; 21:250-258.

Hofferth S, Reid LL. Center for Social Research, University of Michigan. Children's Food Security. Paper presented at annual meeting of the Population Association of America, Chicago. April 1998.

Holben DH. Food Insecurity in the United States: Its Effect on Our Patients. Amer Fam Physician, 2004; 69 (5):1058-1063.

Hromi-Fiedler A, Bermúdez-Millán A, Chapman D, Segura-Pérez S, Damio G, Melgar-Quiñones H, Pérez-Escamilla R. Food insecurity status influences nutrient intakes among pregnant Latinas. The FASEB Journal, 2007;21:829.16.

Hubert HB, Feinleib M, McNamara PM, Castelli WP. Obesity as an independent risk factor for cardiovascular disease: a 26-year follow-up of participants in the Framingham Heart Study. Circulation. 1983;67:969-77.

Huffman GB. Evaluating and Treating Unintentional Weight Loss in the Elderly. Am Fam Physician. 2002;65:640-50.

Jackson AS, Stanforth PR, Gagnon J, Rankinen T, Leon AS, Rao DC, Skinner JS, Bouchard C and Wilmore JH. The effect of sex, age and race on estimating percentage body fat from body mass index: The Heritage Family Study. Intl J Obesity, 2002;26:789-796.

Jeffery RW, French SA. Socioeconomic status and weight control practices among 20 to 45-year-old women. Am. J. Public Health, 1996; 86:1005-1010.

Jelliffe DB, Jelliffe EFP, Zerfas A, Neumann CG. Community nutritional assessment; with special reference to less technically developed countries. Oxford University Press, 1989, New York.

Jenkins KR. Body weight change and physical functioning among young old adults. J. Aging and Health, 2004;16(2):248-66.

Jones SJ and Frongillo EA. Food insecurity and subsequent weight gain in women. Public Health Nutrition, 2007;10:145-151.

Jones SJ, Jahns L, Laraia BA, Haughton B. Lower risk of overweight in school-aged food insecure girls who participate in food assistance. Arch Pediatr Adolesc Med. 2003;157:780-784.

Kaiser LL, Melgar-Quiñonez H, Lamp C, Sutherlin J, Johns M, Harwood J. Food Security and Nutritional Outcomes of Latino Preschoolers. J Am Diet Assoc. 2002;102: 924-929.

Kaleta D, Kwasniewska M, Bednarek-Gejo A, Dziankowska-Zaborszczyk E, Jegier A, Kostka T, Drygas WK. Body weight change and health outcomes in middle-aged men, a prospective study. Przeglad Lekarski, 2005;62(Suppl 3):18-22.

Kaluski DN, Keinan-Boker L, Stern F, Green MS, Leventhal A, Goldsmith R, Chinich A, Berry EM. BMI may overestimate the prevalence of obesity among women of lower socioeconomic status. Obesity, 2007;15(7):1808-1815.

Kendall A, Olson CM, Frongillo EA Jr. Relationship of hunger and food insecurity to food availability and consumption. J Am Diet Assoc, 1996;96(10):1019-24.

Kirkpatrick SI, Tarasuk V. Food insecurity is associated with nutrient inadequacies among Canadian adults and adolescents. J Nutr. 2008;138:604-612.

Kleinman R, Murphy M, Little M, Pagano M, Wehler C, Regal K, Jellinek M. Hunger in children in the United States: potential behavioral and emotional correlates. Pediatrics. 1998;101(1):e3.

Klesges R, Klesges L. Smoking and fear of weight gain. Int J Eating Disord. 1988;7:413-419.

Klesges RC, Eck LH, Isbell TR, Fullton W, Hanson CL. Smoking status: effects on the dietary intake, physical activity, and body fat of adult men. Am J Clin Nuir. 1990;51: 784-9.

Kompoti M, Mariolis A, Alevizos Alevizos A, Kyrazis I, Protopsaltis I, Dimou E, Lentzas I et al. Elevated serum triglycerides is the strongest single indicator for the presence of metabolic syndrome in patients with type 2 diabetes. *Cardiovascular Diabetology* 2006, **5**:21.

Koplan, JP, and WH Dietz. Caloric imbalance and public health policy. JAMA. 282.16 (1999):1579-81.

Kushel MB, Gupta R, Gee L, Haas JS. Housing instability and food insecurity as barriers to health care among low-income Americans. J. Gen Intern Med. 2006;21:71-7.

Kyle U, Genton L, Karsegard L, Slosman D, Pichard, C. Single prediction equation for bioelectrical impedance analysis in adults aged 20-94 y. Nutrition. 2001;17:248-253.

Kyle UG, Bosaeus I, De Lorenzo AD, Deurenberg P, Elia M, Gomez JM, Heitmann LB et al. Bioelectrical impedance analysis - part II: Utilization in clinical practice. Clinical Nutrition. 2004;23:1430-1453.

Laraia BA, Siega-Riz AM, Evenson KR. Self-reported overweight and obesity are not associated with concern about enough food among adults in New York and Louisiana. Prev Med. 2004 Feb;38(2):175-81.

Lee JS and Frongillo EA. Nutritional and Health Consequences Are Associated with Food Insecurity among U.S. Elderly Persons. J Nutr, 2001;131:1503-1509.

Lee JS, Kawakubo K, Kashihara H, Mori K. Effect of long-term body weight change on the incidence of hypertension in Japanese men and women. Intl J Obesity and Related Metabolic Disorders. 2004;28(3):391-5.

Lemieux I, Lamarche B, Couillard C, Pascot A, Cantin B, Dagenais GR, et al. Cholesterol/HDL cholesterol ratio vs. LDL cholesterol/HDL cholesterol ratios as indices of IHD risk in men: the Quebec Cardiovascular Study. *Arch Intern Med*, 2001;161:2685-2692.

Life Science Research Office Expert Panel (LSRO Expert Panel). The Federation of American Societies for Experimental Biology, 1989. In: Food Insecurity and Hunger in the United States: An Assessment of the Measure. National Research Council. 2006.

Life Sciences Research Office (LSRO). S.A. Andersen, (ed). Core Indicators of Nutritional State for Difficult to Sample Populations. J Nutr. 1990;120:1557S-1600S.

Lissner L, Bengtsson C, Lapidus L, Bjorkelnd C. Smoking initiation and cessation in relation to body fat distribution based on data from a study of Swedish women. Am J Public Health. 1992;82:273-275.

Manson JE, Stampfer MJ, Hennekens CH, Willet WC. Body weight and longevity, a reassessment. JAMA. 1987;257(3):353-358.

Martins PA, Hoffman DJ, Fernandes MTB, Nascimento CR, Roberts SB, Sesso R and Sawaya LA. Stunted children gain less lean body mass and more fat mass than their non-stunted counterparts: a prospective study. Br J Nutr. 2004;92:819-25.

Martorell R, Mendoza F, Castillo R. Poverty and stature in children. In: Waterlow JC (ed.). Linear growth retardation in less developed countries: Raven Press. NewYork. 1988. p. 57-73.

McLaughlin T, Abbasi F, Cheal K, Chu J, Lamendola C, and Reaven G. Use of metabolic markers to identify overweight individuals who are insulin resistant. Ann Intern Med. 2003;139:802-809.

McNamara DJ, Min L. Plasma LDL:HDL ratio unchanged following cholesterol challenge. Nutrition Close-Up. 2002;19(3):1-8.

National Cholesterol Education Progarm (NCEP). Adult Treatment Panel III. Available at: http://www.connecticare.com/Provider/LipidManagementCAD.pdf. Accessed, July 26, 2007.

National Heart Lung Blood Institute (NHLBI) Expert Panel. Obesity education initiative expert panel on the identification, evaluation, and treatment of overweight and obesity in adults. NIH Publication Number 00-4084, October 2000.

National Institute of Diabetes and Digestive and Kidney Diseases (NIDDKD). Statistics related to overweight and obesity. NIH Publication No. 96-4158 ed. Washington DC: US Government Printing Office, 1996.

National Institute of Diabetes, Digestive and Kidney Diseases (NIDDKD). National Institute of Health (NIH). Bioelectrical impedance analysis in body composition measurement. Technology Assessment Conference Statement. December 12-14, 1994.

National Research Council Panel to Review the U.S. Department of Agriculture's measurement of food insecurity and hunger. G.S. Wunderlich and J.L. Norwood, (eds). Food insecurity and hunger in the United States. Assessment of the measure. Committee on National Statistics, Division of Behavioral and Social Sciences and Education. National Academies Press, 2006. Washington D.C.

NCEP Expert Panel on detection, evaluation, and treatment of high blood cholesterol in adults. Executive summary of the third report of the National Cholesterol Education Program (NCEP) Expert panel on detection, evaluation, and treatment of high blood cholesterol in adults (Adult Treatment Panel III). JAMA. 2001 May 16;285(19):2486-97.

Neumark-Sztainer D, Goeden C and Story M. Associations between body satisfaction and physical activity in dolescents: Implications for programs aimed at preventing a broad spectrum of weight-related disorders. Eating Disorders, 2004;12:125-137.

Newman AB, Yanez D, Harris T, Duxbury A, Enright PL, Fried LP. Weight change in old age and its association with mortality. American Geriatrics Society. 2001; 49:1309-1318.

Nord M, Andrews M and Carlson S. Household Food Security in the United States 2005. Food Assistance & Nutrition Research Program. ERS Economic Research Report No. 29, USDA, 2005. Accessed July 9, 2007 from http://www.ers.usda.gov /Publications/ERR29.

Nord M, Andrews M, Carlson S. Household food security in the United States, 2004. Economic Research Report No. 11. Washington, DC: U.S. Department of Agriculture, Economic Research Service, 2005.

Nord M, Andrews M, Carlson S. Household food security in the United States, 2006. Economic Research Report No. 49. Washington, DC: U.S. Department of Agriculture, Economic Research Service, 2007.

Nord M, Andrews M, Winicki J. Frequency and duration of food insecurity and hunger in U.S. Households. J Nutr Educ Behavior. 2002;34(4):194-201.

Nord M. Characteristics of low-income households with very low food security. An analysis of the USDA GPRA food security indicator. United States Department of Agriculture. Economic Research Service. Economic Information Bulletin number 25, May 2007b.

Olson CM. Nutrition and health outcomes associated with food insecurity and hunger. J Nutr, 1999;129:521S-524S.

Omran ML, Morley JE, Assessment of Protein Energy Malnutrition in Older Persons, Part II: Laboratory Evaluation. Nutrition. 2000;16:131-140.

Ozanne SE, Fernandez-Twinn D, Nicholas Hales C. Fetal growth and adult diseases. Seminars in Perinatology, 28(1);2004:81-87

Patt MR, Yanek LR, Moy TF and Becker DM. Assessment of global coronary heart disease risk in overweight and obese African-American Women. Obesity Research. 2003;11:660-667.

Peeters A. Obesity in adulthood and its consequences for life expectancy: A life-table analysis. Annals of Internal Medicine. 2003; 138:24-32.

Pi-Syner F. Comorbidities of overweight and obesity: Current evidence and research issues. Med Sci Sports Exerc. 1999;31:S602-S608.

Polivy J. Psychological consequences of food restriction. J Am Diet Assoc. 1996;96:589-92.

Radimer K L, Allsopp R, Harvey PWJ, Firman DW, Watson EK. Food insufficiency in Queensland. Aust. N.Z. J Public Health. 1997;21: 303-310.
Radimer K. Measurement of household food security in the USA and other industrialized countries. Pub Health Nutr. 2002;5(6A):859-864.

Radimer KL, Olson CM, Campbell CC. Development of indicators to assess hunger. J Nutr. 1990;120:1544-8.

Radimer KL, Olson CM, Greene JC, Campbell CC, Habicht J-P. Understanding hunger and developing indicators to assess it in women and children. J Nutr Educ, 1992;24:S36-45.

Rexrode KM, Carey VJ, Hennekens CH, et al. Abdominal adiposity and coronary heart disease in women. JAMA, 1998;280:1843-8.

Robertson AR, Brunner E, Shilham A. Food is a political issue. In: Marmot MWR, ed. Social Determinants of Health. Oxford: Oxford University Press; 1999.

Rolls BJ. The role of energy density in the overconsumption of fat. J Nutr, 2000;130:268S-271S.

Rose D, Gundersen C, Oliveira V. Socio-economic determinants of food insecurity in the United States: Evidence from the SIPP and CSFII Datasets. Technical Bulletin 1869. Economic Research Service, U.S. Department of Agriculture, Washington, DC. 1998.

Rose D, Oliveira V. Nutrient Intakes of Individuals from Food-Insufficient Households in the United States. Am J Public Health. 1997;87(12):1956-1961.

Rose D. Economic determinants and dietary consequences of food insecurity in the United States. J Nutr, 1999;129: 517S-520S.

Rose, D. Economic determinants and dietary consequences of food insecurity in the United States. J Nutr, 2000;129(Suppl 2): 517s-520s.

Roubenoff R, Baumgartner RN, Harris TB, et al. Application of bioelectrical impedance analysis to elderly population. J Gerontol. 1997;52A:M129.

Rowland MI. Self-reported weight and height. Am J Clin Nutr, 1990;52(6):1125-33.

Rush TJ, Victor GN, Irwin JD, Stitt LW, HE M. Food insecurity and dietary intake of immigrant food bank users. Canadian J Diet Practice Research, 2007;68(2):73-78.

Sarlio-Lahteenkorva S, Lahelma E. Food insecurity is associated with past and present economic disadvantage and body mass index. J Nutr. 2001;131:2880-2884.

Scrimshaw NS. Historical concepts of interactions, synergism and antagonism between nutrition and infection. J. Nutr, 2003;133(1):316S-321S.
Seligman HK, Bindman AB, Vittinghoff E, Kanaya AM, Kushel MB. Food insecurity is associated with diabetes mellitus: Results from the National Health Examination and Nutrition Examination Survey (NHANES) 1999-2002. Soc Gen Internal Med. 2007;22:1018-1023.

Shariff ZM, Khor GL. Obesity and household food insecurity: evidence from a sample of rural households in Malaysia. Eur J Clin Nutr. 2005 Sep;59(9):1049-58.

Sharkey JR. Risk and presence of food insufficiency are associated with low nutrient intakes and multimorbidity among homebound older women who receive home-delivered meals. J Nutr, 2003;133:3485-3491.

Shin-Yi C, Grossman M, Saffer H. An economic analysis of adult obesity: results from the Behavioral Risk Factor Surveillance System. J. Health Economics, 2004;23:565-587.

Silventoinen K, Kaprio J, Koskenvuo M, Lahelma E. The association between body height and coronary heart disease among Finnish twins and singletons. Int. J. Epidemiol, 2003;32:78-82.

Singer E and Hess J. Evaluation of the pretest results for the food security supplement to April 1995 CPS. US Bureau of the Census, Center for Survey Methods Research, Washington, DC, 1994.

Snead DB, Birge SJ, Kohrt WM. Age-related differences in body composition by hydrodensitometry and dual-energy X-ray absorptiometry. The American Physiological Society, 1993;771-775.

Snijder MB, van Dam RM, Visser M, Seidell JC. What aspects of body fat are particularly hazardous and how do we measure them? Int J Epidemiol. 2006;35:83-92.

STATA Corporation. STATA Statistical Software. Release 10.0 SE. STATA Corporation, 2007. College Station, TX.

National Institute of Diabetes and Digestive and Kidney Diseases (NIDDKD). Statistics Related to Overweight and Obesity. NIH Publication No. 96-4158 ed. Washington DC: US Government Printing Office, 1996.

Stefanick M, Mackey S, Sheehan M, Ellsworth N, Askell WL and wood PD. Effects of diet and exercise in men and postmenopausal women with low levels of HDL cholesterol and high levels of LDL cholesterol. N Engl J Med, 1998;339:12-20.

Stuff JE, Casey PH, Szeto KL. Household food insecurity is associated with adult health status. J Nutr. 2004;134:2330-2335.

Sullivan DH, Liu L, Roberson PK, Bopp MM, Rees JC. Body weight change and mortality in a cohort of elderly patients recently discharged from the hospital. J. American Geriatrics Society, 2004;52(10):1696-701.

Tarasuk VS. Household food insecurity with hunger is associated with women's food intakes, health and household circumstatnces. J. Nutr, 2001;131:2670-6.

Townsend MS, Peerson J, Love B, Achterberg C, Murphy SP. Food insecurity is positively related to overweight in women. J Nutr. 2001;131:1738-45.

Troisi RJ, Heinold JW, Vokonas PS, and Weiss ST. Cigarette smoking, dietary intake, and physical activity: effects on body fat distribution-the Normative Aging Study. Am J Clin Nutr 1991;53:1104-11.

U.S. Census Bureau. Census 2000. U.S. Department of Commerce, Economics and Statistics Administration. Accessed June 26, 2007. From: http://www. census.gov.

United States Agency for International Development (USAID). Policy Determination 19, Definition of Food Security, April 13, 1992. Washington, DC, 1992.

United States Department of Agriculture (USDA). Guide to measuring household food security, revised 2000. G. Bickel, M. Nord, C. Price, W. Hamilton, J Cook, (eds). United States Department of Agriculture. Food and Nutrition Service. Office of Analysis, Nutrition and Evaluation. Alexandria, 2000.

United States Department of Agriculture (USDA). Household Food Security in the United States, 2006. M. Nord, M. Andrews, S. Carlson (eds). Food Assistance and Nutrition Research Program. ERS Economic Research Report No. 49. Available at: www.ers.usda.gov/Publications/ERR49. Accessed November 18, 2007.

USDA and DHHS. Conference on food security measurement and research: Papers and proceedings. January 21-22, 1994. Washington, DC.

USDA. Measuring Food Security in the United States. Household Food Security in the United States, 2004. Economic Research report No 11, 2004:2-30.

USDA. What factors account for state to state differences in food insecurity? J. Bartfeld, R. Dunifon, M Nord and S. Carlson (eds). Economic Research Service. Economic Information Bulletin No. 20. Dec. 2006.

van Dam RM, Willet WC, Manson JE, Hu Frank B. The relationship between overweight in adolescence and premature death in women. Ann Intern Med. 2006;145:91-97.

Vozoris NT, Tarasuk VS. Household food insufficiency is associated with poorer health. J Nutr. 2003;133:120-126.

Walker SP, Wachs TD, Gardner JM, Lozoff B, Wasserman GA, Pollitt E. Child development: Risk factors for adverse outcomes in developing countries. Lancet, 2007;369:145-157.

Wannamethee SG, Saper AG and Walker M. Weight change, body weight and mortality: the impact of smoking and ill health. Int. J. Epidemiol, 2001;30:777-786.

Washington DC: US Government Printing Office, 1996.

Whitaker RC, Phillips SM, Orzol SM. Food insecurity and the risks of depression and anxiety in mothers and behavior problems in their preschool-aged children. Pediatrics, 2006;118(3):859-868.

Wicks R, Trevena LJ, Quine S. Experiences of food insecurity among urban soup kitchen consumers: insights for improving nutrition and well-being. J Am Diet Assoc, 2006;106:921-924.

Wilde P, Ranney C. A monthly cycle in food expenditure and intake by participants in the U.S. Food Stamp Program. Discussion Paper no. 1163-98, Institute for Research on Poverty, University of Madison-Wisconsin. 1998.

Wilde PE, Peterman JN. Individual weight change is associated with household food security status. J Nutr. 136: 1395-1400, 2006.

Willett WC. Nutritional Epidemiology, 2nd edition, New York: Oxford University Press, 1998.

Willett WC, Manson JE, Stampfer MJ, Colditz GA, Rosner B, Speizer, FE and Hennekens CH. Weight, weight change and coronary heart disease in woman. Risk within the 'normal' weight range. JAMA. 1995;272:461-465.

Winkleby M, Robinson T, Sundquist J. Ethnic variations in cardiovascular disease risk factors among children and young adults. JAMA. 1999;281:1006-1013.

World Food Summit. Rome Declaration on World Food Security 1996. Available at: http://www.fao.org/ wfs/index_en.htm. Accessed December 21, 2004.

Wright ME, Chang SC, Schatzkin A, Albanes D, Kipnis V, Mouw T, Hurwitz P, Hollenbeck A, Leitzmann MF. Prospective study of adiposity and weight change in relation to prostate cancer incidence and mortality. Cancer. 2007 Feb 15;109(4):675-84.

Wu Z, Schimmele CM. Food insufficiency and depression. Sociological Perspectives, 2006;48(4):481-504.

Wunderlich GS, Norwood JL, eds. Food Insecurity and Hunger in the United States: An Assessment of the Measure. Washington, DC: The National Academies Press, 2006.

Xitron Technologies, Inc. HYDRA ECF/ICF Bio-Impedance Spectrum Analyzer (Model 4200). Operating Manual, Revision 1.01, 2005. San Diego.

Zizza CA, Duffy P, and Gerrior SA. Food insecurity is not associated with lower energy intakes. Obesity, 2008. DOI:10.1038/oby.2008.288.

APPENDIX 1

The Questions Used to Assess the Food Security of Households in the CPS Food Security Supplement

1. "I/We worried whether my/our food would run out before I/we got money to buy more." Was that often, sometimes, or never true for you/your household 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 12months?

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 you couldn't afford enough food? (Yes/No)

8. In the last 12 months, did you lose weight because you didn't have 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 are asked only if the household included children age 0-18)

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)

(Source: Nord, Andrews and Carlson, 2005)

APPENDIX 2

The United States Household Food Security Scale Ordered by Severity Level

Number of Affirmative Responses: (Out of 18) Households With Children	(Out of 10) Households Without Children	1998 Food Security Scale Values	Food Security Status Level: Code	Category
0	0	0.0	0	Food Secure
1		1.0		
	1	1.2		
2		1.8		
	2	2.2		
3		2.4	1	Food Insecure Without Hunger
4		3.0		
	3	3.0		
5		3.4		
	4	3.7		
6		3.9		
7		4.3		
	5	4.4		
8		4.7	2	Food Insecure With Hunger, Moderate
	6	5.0		
9		5.1		
10		5.5		
	7	5.7		
11		5.9		
12		6.3		

APPENDIX 2 (Continued)

The United States Household Food Security Scale Ordered by Severity Level

Number of Affirmative Responses:		1998 Food Security Scale Values	Food Security Status Level	
(Out of 18) Households With Children	(Out of 10) Households Without Children		Code	Category
	8	6.4	3	Food Insecure With Hunger, Severe
13		6.6		
14		7.0		
	9	7.2		
15		7.4		
	10	7.9		
16		8.0		
17		8.7		
18		9.3		

(Source: USDA, 2000; Calculated by ERS from August 1998 Current Population Survey Food Security Supplement data).