The association between food insecurity and health behavior outcomes

by

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Abstract

The purpose of this dissertation is to provide a better understanding of the health and behavior 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 1999-2010. The first study examined the associations between adult food security status and sleep duration, sleep latency, and sleep complaints reported to a health care professional. This study included 5,637 men and 5,264 women (≥ 22 y) who participated in the NHANES 2005-2010. The results showed that very low food secure women reported significantly shorter sleep duration than fully food secure women ($P<0.01$). Among men those who were marginally food secure, low food secure, and very low food secure reported significantly longer sleep latency than fully food secure men ($P<0.05$), but no association regarding sleep latency was observed among women. Among both men and women, marginally food secure, low food secure, and very low food secure participants were more likely to report sleep complaints than their fully food secure counterparts ($P<0.05$). The second study determined whether the association between food insecurity and asthma is moderated by recent tobacco exposure among children. Our population-based sample included 15417 participants in the National Health and Nutrition Examination Survey 1999-2010. The results showed that among children without recent tobacco exposure, those who were living in food insecure (Odds Ratio 1.42; 95% CI, 1.05-1.93) households were more likely to report asthma compared to those in fully food secure households. Among children with recent tobacco exposure, an association between food insecurity and asthma was not

observed. The third study estimated the misclassification of young-age children's tobacco exposure and its association with socioeconomic characteristics, including children's sex, age, race/ethnicity, family income, numbers of household rooms, and household food security status. Our population-based sample included 6328 participants (3-10y) in the National Health and Nutrition Examination Survey 1999-2010. The results showed that children who were younger (Adjusted OR 1.38, 95% CI 1.16-1.64), Non-Hispanic Black (Adjusted OR 1.38, 95% CI 1.16-1.64), living in low PIR families (Adjusted OR 1.38, 95% CI 1.10-1.71), and living in smaller housing (Adjusted OR 1.50, 95% CI 1.21-1.87) were more likely to be misclassified of tobacco exposure than their counterparts. In the crude model, children living in food insecure household were more likely to be misclassified of tobacco exposure than those living in food secure household (OR 1.27, 95% CI 1.04-1.55), but the association was attenuated after other characteristics taken into account in the full model. Sex was not found to be associated with misclassification of tobacco exposure. These results indicated the adverse health and behavior outcomes of food insecure persons and suggested that public health efforts need to be increased to improve food security status in the United States.

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List of Abbreviations

BMI	Body Mass Index
CPS	Current Population Survey
LSRO	Life Sciences Research Office
FSS	Food Security Supplement
FSSM	Food Security Survey Module
NCHS	National Center for Health Statistics
NHANES	National Health and Nutrition Examination Survey
MEC	Mobile Examination Center
PIR	Poverty Income Ratio
SES	Socioeconomic Status
SNAP	Supplemental Nutrition Assistance Program
USDA	United States Department of Agriculture
USDHHS	United States Department of Health and Human Services

Chapter 1 General Introduction

The purpose of this dissertation is to provide a better understanding of the health and behavior status of food insecure persons in the United States. This dissertation is organized into five chapters. Chapter 1 is the general introduction. Chapter 2 presents a review of the literature. Chapter 3 is a manuscript on the associations between food insecurity and poor sleep outcomes among adults. Chapter 4 is a manuscript on tobacco exposure's modification effect of the associations between food insecurity and asthma among children. Chapter 5 is a manuscript on socioeconomic characteristics and misclassification of tobacco exposure among children.

Chapter 2 Review of Literature

Definitions of food security status

Numerous and various terms have been used in describing food security because of its multi-disciplinary and multi-sectoral nature (Jone et al., 2013). The concept of food security has been explored in several academic disciplines, including agriculture, anthropology, economics, nutrition, public policy, and sociology, and each discipline defines and discusses food security in different terms (Jone et al., 2013). Thus, in 1990, the Life Sciences Research Office (LSRO) of the Federation of American Societies for Experimental Biology (FASEB) developed a consensus to define food security in the U.S. as "access by all people at all times to enough food for an active, healthy life and includes at a minimum: a) the ready availability of nutritionally adequate and safe foods, and b) the assured ability to acquire acceptable foods in socially acceptable ways, without resorting to emergency food supplies, scavenging, stealing, and other coping strategies. (LSRO, 1990)" In contrast, the definition of food insecurity includes food-related conditions of uncertainty, insufficiency, and socially unacceptability (USDA, 2000). Food insecurity happens "whenever the availability of nutritionally adequate and safe foods or the ability to acquire acceptable foods in socially acceptable ways is limited or uncertain. (LSRO, 1990)" The conditions of voluntary fasting, dieting, and skipping meals, as well as being too busy to eat are not reflections of the definition of food insecurity. Thus, people who are suffering from hunger, which is an uneasy or painful sensation caused by a lack of food, may be potentially, although not necessarily, experiencing food insecurity (USDA, 2000).

Food insecurity is a food related circumstance resulting from financial resource constraint. It occurs only for the reason that the household does not have enough food or money to buy food (USDA, 2000). Although food insecurity is mostly linked to poverty, a one-to-one correspondence between food insecurity and income level does not exist (Rose, 1999). Research shows that there is still a small percentage of households above poverty line experiencing food insecurity, while many low income households appear to be food secure (USDA, 2000).

Measurement of food security status

The estimates of food security status are strong drivers of governmental policy, and federal as well as private food assistant programs. Therefore, a reliable measurement of food security status is important to monitor the extent and severity of food insecurity in U.S. households over time (USDA, 2014). Food security status measurement is also important to provide vital data on understanding the causes and consequences of food insecurity. Frequent causes of food insecurity are socioeconomic factors that affect its extent in a household. Consequences of food insecurity could be health concerning issues, because dietary intake is one of the most direct inputs that affect health.

Due to the multi-disciplinary and multi-sectoral nature of food security status (Jone et al., 2013), no single indicator could completely measure the full range of food security status (Carlson et al., 1999). It was demanded to develop a module that could indicate the extent and severity of food security status, based on food-related information of a variety of conditions, experiences, and behaviors (USDA, 2000). In 1995, the USDA started to estimate the food security status of U.S. households using a series of questionnaires as a supplement to the U.S. Census Bureau's Current Population Survey (CPS) (NRC, 2006). The CPS Food Security Supplement (FSS) established a core module of food security scales based on obtaining the following household conditions, events, behaviors, and subjective reactions (USDA, 2000):

1) *Anxiety that the household food budget or food supply may be insufficient to meet basic needs;*
2) *The experience of running out of food, without money to obtain more;*
3) *Perceptions by the respondent that the food eaten by household members was inadequate in quality or quantity;*
4) *Adjustments to normal food use, substituting fewer and cheaper foods than usual;*
5) *Instances of reduced food intake by adults in the household, or consequences of reduced intake such as the physical sensation of hunger or loss of weight; and*
6) *Instances of reduced food intake, or consequences of reduced intake, for children in the household.*

The final set of 18-item questions was identified from 70 questions in the FSS to cover the full range of severity of current food security status for U.S. household both with and without children (USDA, 2014). The severity of food insecurity ranges from worrying about food expenditures to assessing the frequency of skipping or cutting meals or losing weight because of a lack of food over 12 months. This stable, robust, well-validated, and reliable 18-item Food Security Survey Module (FSSM), shown in Table 2-1, estimates food security status based on household level (Carlson et al., 1999; USDA, 2000). If a household has any child aged 0-17y, the full 18-item questions (Q1-18) will be asked, and if no children are included in the household, only 10 items (Q1-10) will be asked. Some questions (Q4, Q6-9, Q14-16, Q18) have obvious response categories such as "yes" or "no". Other questions (Q1-3, Q5, Q10-13, and Q17) are considered to be either "affirmative" with the responses of both "often true" and "sometimes true", or "negative" with a response of "never true". In order to estimate food security status on scale or category, it is important to give a value to each "affirmative" or "negative" response of each question; each affirmative response is coded as 1 and each negative response is coded as 0.

Table 2-1. USDA 18-item Food Security Survey Module (USDA, 2000; USDA, 2014)

Question Number	Question	Affirmative Responses (code=1)	Negative Responses (code=0)
Q1	We worried whether our food would run out before we got money to buy more." Was that often, sometimes, or never true for you in the last 12 months?	Often true; Sometimes true	Never true
Q2	The food that we bought just didn't last and we didn't have money to get more." Was that often, sometimes, or never true for you in the last 12 months?	Often true; Sometimes true	Never true
Q3	We couldn't afford to eat balanced meals." Was that often, sometimes, or never true for you in the last 12 months	Often true; Sometimes true	Never true
Q4	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)	Yes	No
Q5	(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?	Often true; Sometimes true	Never true
Q6	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)	Yes	No

Q7	In the last 12 months, were you ever hungry, but didn't eat, because there wasn't enough money for food? (Yes/No)	Yes	No
Q8	In the last 12 months, did you lose weight because there wasn't enough money for food? (Yes/No)	Yes	No
Q9	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)	Yes	No
Q10	(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?	Often true; Sometimes true	Never true
Q11	(Questions 11-18 were asked only if the household included children age 0-17) 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?	Often true; Sometimes true	Never true
Q12	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?	Often true; Sometimes true	Never true
Q13	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?	Often true; Sometimes true	Never true
Q14	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)	Yes	No
Q15	In the last 12 months, were the children ever hungry but you just couldn't afford more food? (Yes/No)	Yes	No
Q16	In the last 12 months, did any of the children ever skip a meal because there wasn't enough money for food? (Yes/No)	Yes	No
Q17	(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?	Often true; Sometimes true	Never true
Q18	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)	Yes	No

There are two dominant methods to determine food security status by calculating the affirmative scores obtained from the FSSM questions (USDA, 2000). Both methods can represent the underlying phenomenon and have several categories or ranges of severity of food security status. The fullest food security and the most severe condition of food insecurity are at the two end points of a spectrum. The level of food security for each household can fall anywhere on this spectrum. In other words, the phenomenon of food insecurity is a continuum of increasingly severe conditions, experiences, and the household's diet behavioral responses to the phenomenon (USDA, 2000; Carlson et al., 1999).

One of the two forms of the measurement of food security status is the continuous food security scale (Table 2-2), which is represented on a standard 0-10 metric (USDA, 2000). A standard 0-10 metric is chosen because of its simplicity and familiarity for using. The food security scale can actually measure the severity of food insecurity: a scale value of 0 captures the fully food secure, which is the absence of the measured condition, while a value of nearly 10 represents the most severely food insecure condition.

Table 2-2. Standard Metrics for FSSM scale values.

No. of affirmative responses		Standard U.S. food security scale value (0-10 metric)
Household with children	Household without children	
0	0	0.0
1	-	1.0
-	1	1.2
2	-	1.8
-	2	2.2
3	-	2.4
4	-	3.0
-	3	3.0
5	-	3.4
-	4	3.7
6	-	3.9
7	-	4.3
-	5	4.4
8	-	4.7

-	6	5.0
9	-	5.1
10	-	5.5
-	7	5.7
11	-	5.9
12	-	6.3
-	8	6.4
13	-	6.6
14	-	7.0
-	9	7.2
15	-	7.4
-	10	7.9
16	-	8.0
17	-	8.7
18	-	9.3

The other form of the food security measurement is the categorical food security status-level (Table 2-3), which captures the meaningful ranges of food insecurity's severity that are defined on the underlying scale (USDA, 2000). This categorical form contains four levels of food security status (USDA, 2014). For both households with children and without children, the household is considered to be fully food secure if there are 0 affirmative items in the response and marginally food secure if 1-2 items are affirmative. Low food security happens when a household with children has 3-7 affirmative answers and a household without children has 3-5 affirmative answers. Very low food security occurs when there are 8-18 affirmative responses for household with children and 6-10 affirmative responses for household without children. Low and very low food security classifications were referred to as food insecurity. Fully food secure indicates there are no problems or anxieties regarding food, marginally food secure means household members are anxious about food or perceive problems in attaining food, but food quality, variety, and quantity are not reduced. Low food security refers to a condition in which the quality, variety, and desirability of food are reduced yet quantity remains adequate. Very low food security occurs when eating patterns are disrupted and food quantity is reduced due to inadequate resources (NRC, 2006).

Table 2-3. U.S. household food security category

No. of affirmative responses		Food security category
Household with children	Household with no children	
0	0	Fully food secure
1-2	1-2	Marginal food security
3-7	3-5	Low food security
8-18	6-10	Very low food security

Labels and revisions of U.S. household food security status categories

Although the FSSM exhibits good statistical “fit” that has remained unchanged over the years, the cut-off points of the scale and household food security categories that describe the severity of food insecurity were revised by the USDA (Alaimo 2004). In 1995, USDA used four labels to describe the phenomenon of food security status, those were food secure, food insecure without hunger, food insecure with moderate hunger, and food insecure with severe hunger (Table 2-4, 2-5) (Carlson et al., 1999). Then in 1999, the term “marginal food security” was added in the food security category: fully food secure, marginally food secure, food insecure without hunger, and food insecure with hunger (USDA, 2000). In 2006, Committee on National Statistics panel determined to use the labels without the word “hunger”, as hunger represents an individual-level physiological condition that may potentially, although not necessarily, result from food insecurity, while food insecurity is a household-level economic and social condition (NRC, 2006). From then to date, USDA use these four new labels to the public: full food security, marginal food security, low food security, and very low food security (USDA, 2014).

Table 2-4. Labels' comparison of U.S. household food security status categories since 1995 (based on 18-item question for household with children).

1995		1999		2006	
Food security category	No. of affirmative responses	Food security category	No. of affirmative responses	Food security category	No. of affirmative responses
Food secure	0-2	Fully food secure	0	Fully food secure	0
Food insecure without hunger	3-7	Marginal food security	1-2	Marginal food security	1-2
Food insecure with moderate hunger	8-12	Food insecure without hunger	3-7	Low food security	3-7
Food insecure with severe hunger	13-18	Food insecure with hunger	8-18	Very low food security	8-18

Table 2-5. Labels' comparison of U.S. household food security status categories since 1995 (based on 10-item question for household without children).

1995		1999		2006	
Food security category	No. of affirmative responses	Food security category	No. of affirmative responses	Food security category	No. of affirmative responses
Food secure	0-2	Fully food secure	0	Fully food secure	0
Food insecure without hunger	3-5	Marginal food security	1-2	Marginal food security	1-2
Food insecure with moderate hunger	6-8	Food insecure without hunger	3-5	Low food security	3-5
Food insecure with severe hunger	9-10	Food insecure with hunger	6-10	Very low food security	6-10

Surveys estimating food security status in the US

Several surveys use the U.S. 18-item FSSM to collect information on food security status in the US, including CPS-FSS and National Health and Nutritional Examination Survey (NHANES). CPS is widely accepted as an authoritative source of statistical information. CPS-FSS is conducted by the U.S. Census Bureau for the Economic Research Service (ERS) of the U.S. Department of Agriculture (USDA) to estimate the prevalence of food security and insecurity in subpopulations (US Census Bureau, 2012). However, CPS does not collect data on health or health behavior characteristics, so that it is difficult to do research on linking food security status to health and behavior outcomes using CPS. NHANES is conducted by the National Center for Health Statistics (NCHS) to collect health and nutrition information for the noninstitutionalized U.S. civilian population since 1960 (CDC, 2013). The NHANES includes household and personal interviews, standardized physical examinations, and laboratory tests, which make it possible to estimate associations between food insecurity and health consequences.

Prevalence of food security status

The latest CPS-FSS showed that about 14.3%, which was 17.5 million households, were food insecure at some time during 2013 (USDA, 2014). Those households were, at times, unable to get adequate food for one or more household members because they could not afford enough food. Most of these food insecure households did not suffer from disrupted eating patterns and reduced food intake. They might depend on a few basic foods and reduce variety in their diets. However, about 5.6%, which was 6.8 million households, experienced very low food security. Those households had at least one household member, at some time during the year, experienced substantial reductions or disruptions in food intake because they had insufficient money and other resources for food. The remaining 85.7 % U.S. households were food secure throughout the year.

Among households with children, 19.5% households experienced food insecurity at some time during the year (USDA, 2014). Those households that had both children and adults experienced food insecure occupied 9.9% of households having children. These households were unable to provide adequate and nutritious food for their children. Because children are mostly protected by adults in households from disrupted eating patterns and reduced food intake, only 0.9% of households with children had both children and adults experience very low food security at times during 2013.

The prevalence of food insecurity varies among households with different socioeconomic characteristics. Food insecurity is strongly related to income (Rose, 1999; USDA, 2000). In 2013, 42.1% of households with annual incomes below the Federal poverty line, which is household income-to-poverty ratio under 1, were food insecure, compared with 6.7% of those with incomes above 185% of the poverty line (USDA, 2014). Food insecurity were less prevalent than the national average (14.3%) for households with the following characteristics:

1) Married-couple families with children (12.8%)
2) Households with more than one adult and no children (9.9%)
3) Households with elderly persons (8.7%)
4) Non-Hispanic white households (10.6%)
5) Households headed by non-Hispanics of other, or multiple, races (11.7%)
6) Households with incomes above 185% of the poverty line (6.7%)

7) Households located in suburbs and other metropolitan areas outside principal cities (12.1%)
8) Households located in the Northeast (12.4%)

Whereas food insecurity were more prevalent than the national average (14.3%) for:

1) Households with children (19.5%)
2) Households with children under 6 y (20.9%)
3) Households with children headed by a single woman (34.4%)
4) Households with children headed by a single man (23.1%)
5) Non-Hispanic Black households (26.1%)
6) Hispanic households (23.7%)
7) Households with incomes below 185% of the poverty line (34.8%)
8) Households located in principal cities of metropolitan areas (16.7%)
9) Households in the South (15.7%)

Federal food and nutrition assistance programs

The U.S. Department of Agriculture's Food and Nutrition Service (FNS) administers 15 domestic food and nutrition assistance programs. The three large programs are: the Supplemental Nutrition Assistance Program (SNAP), formerly the Food Stamp Program; the National School Lunch Program (NSLP); and the Special Supplemental Nutrition Program for Women, Infants, and Children (WIC). SNAP, the largest of the three programs, provides eligible low-income households with monthly benefits to purchase approved food items (FNS, 2014). NSLP provides nutritionally balanced, low-cost or free lunches to low-income children in public and nonprofit private schools and residential child care institutions each school day (FNS, 2015a). WIC provides supplemental foods, health care referrals, and nutrition education for low-income pregnant, breastfeeding, and non-breastfeeding postpartum women, and to infants and children under 5 y old, who are found to be at nutritional risk, living in low-income families (FNS, 2015b).

Health consequences of food insecurity

In 1991, Campbell (1991) proposed two sets of potential consequences of food insecurity, which are direct physical and physiologic symptoms of poor nutritional status and the consequences of a suboptimal nutritional status. She pointed out that food insecurity could directly or indirectly result in hunger, malnutrition, poor physical health, and lower overall quality of life through poor nutritional status. After that, numerous and various reports have been published on the health consequences of food insecurity, including poor nutritional status, and physical and mental health (Drewnowski and Darmon, 2005; Monsivais and Drewnowski, 2007; Dixon et al., 2001; Rose, 1999; Casey et al., 2004; Seligman et al., 2010; Tayie and Zizza, 2009a ; Tayie and Zizza, 2009b; Xu et al., 2011; Ding et al., 2014; Cook et al., 2004; Weinreb et al., 2002; Alaimo et al., 2001; Cook et al., 2006; Skalicky et al., 2006; Alaimo et al., 2002; Whitaker et al., 2006; Casey et al., 2005).

Because food insecure households have limited available resources to afford food, they consume less expensive foods than food secure households (Drewnowski and Darmon, 2005; Monsivais and Drewnowski, 2007). Less expensive foods could be high in refined grains, added sugars, saturated/trans fat and low in nutrients. For the most severe condition in food insecure households, they have disrupted eating patterns, even skipping meals, but these poor eating patterns do not mean that they have less energy intake (Zizza et al., 2008). Food insecure households consume lower levels of fruits, vegetables, and dairy products (Dixon et al., 2001). Members from food insecure households consume less vitamins and minerals, which could increase the risk of nutrient deficiencies, compared to members from food secure households (Rose, 1999). Members from food insecure households were found to have lower serum concentrations of vitamin A, vitamin E, and three carotenoids (α-carotene, β-cryptoxanthin and lutein/zeaxanthin) (Dixon et al., 2001).

Food insecurity is widely recognized as a serious public health problem. Among both children and adults, food insecurity has been reported to be associated with inadequate intake of several important nutrients, cognitive developmental deficits, behavioral and psychosocial dysfunction, and poor health (Rose, 1999; Casey et al., 2004). Among adults, food insecurity has been linked to obesity, impaired physical performance poor self-reported health status, food allergies, and multiple chronic conditions, including obesity, diabetes, hypertension, hyperlipidemia, and heart disease (Seligman et al., 2010; Tayie and Zizza, 2009a ; Tayie and Zizza, 2009b; Xu,2011; Ding et al., 2014). Several studies have observed the status of food insecurity is associated with women's status of depression, increased risk of maternal anxiety, and both acute and chronic stress (Heflin et al., 2005; Hadley and Patil, 2006; Tsai et al., 2012; German et al., 2011; Hamelin et al., 1999; Jilcott et al., 2011). Children, who live in households with adults experiencing food insecurity, may not experiencing food insecurity directly since they may be protected by adults. Even though, these children has been related to a range of poorer physical heath, more delayed neuropsychological development, worse scores on standardized tests of academic achievement, and even poorer quality of life, compared with those who live in food secure households (Cook et al., 2004; weinreb et al., 2002; Alaimo et al., 2001; Cook et al., 2006; Skalicky et al., 2006; Alaimo et al., 2002; Whitaker et al., 2006; Casey et al., 2005).

Several studies have found that food insecurity is linked to asthma among children (Kirkpatrick et al., 2010; McIntyre et al., 2000; Wehler et al., 1995). McIntyre et al. (2000) stated that the rate of asthma were higher among children who experienced very low food security than those who were food secure. Kirkpatrick et al. (2010) observed that youth who experienced repeated episodes of very low food security were more likely to have asthma than those who were food secure. However, asthma was not related to those children who experienced very low food insecurity. When child and youth were combined, there was an association between ever experiencing very low food security and asthma among girls, but not boys.

Several modifiable, lifestyle-related health behaviors, including poor diet quality, inadequate sleep, smoking, and physical inactivity have also been identified to increase the risk of various chronic conditions and of premature mortality (Pronk et al., 2004). Few studies, to our knowledge, have examined these lifestyle-related health behaviors, other than dietary, among food insecure populations.

Sleep behavior

For almost everyone, sleep on a daily basis is an ancestral and primitive behavior (Cappuccio et al., 2010a). Sleep not only serve as a central nervous system restitution, but also provides the same service for the entire physiological system (Akerstedt and Nilsson, 2003). Sleep is defined by a combination of specific impression from an electroencephalogram, electrooculogram, and electromyogram. The polysomnogram classifies sleep into the following states:

1) Stage 1 has relatively high muscle tonus and often has slow eye movements.
2) In stage 2, muscle tonus falls further and eye movements stop. This stage serves basic recovery and occupies half of the sleep period.
3) Slow wave sleep/Deep sleep, includes stage 3 and 4. These two stages are usually grouped together. Muscle tonus falls further and these two stages provides the daily process of restitution, including increase secretion of growth hormone, suppression of cortisol secretion, and lower metabolism. Slow breathing, low heart rate, and low cerebral blood flow are observed in these two stages.
4) Rapid eye movement sleep is a totally different stage, in which we normally dream in this stage. It is characterized by a virtual absence of muscle tonus in antigravity muscles and a largely active brain.

The metabolic rate, such as heart rate, respiratory rate, blood pressure, and body temperature, is increased above the resting waking levels in sleep. These stages usually progress cyclically from 1 through rapid eye movement and then followed by stage 1 again (Akerstedt and Nilsson, 2003).

Sleep outcomes and health consequences

Healthy People 2020 suggests on average adults sleep ≥ 8 h/day for those aged 18-21 y and ≥ 7 h for those aged ≥ 22 y, on average, during a day (USDHHS, 2013). However, researchers have noted that the average duration of sleep has decreased over the past century among adults because of longer working hours, more shift-work, and the 24-7 availability of food and recreational activities (National Sleep Foundation et al., 2002; Akerstedt and Nilsson, 2003). In 2002, the “Sleep in America” Poll showed that adults slept on average 6.9 h during weekdays and 7.5 h on weekends (National Sleep Foundation, 2002). More than one third of adults reported having less than 7 h of sleep on weekdays, and more than two thirds had less than 8 h of sleep on weekdays. Males reported shorter sleep duration than females (6.7 h vs. 7.0 h). Adults who tended to sleep less were more likely to be between the ages of 18-29 y (6.9 h) and 30-64 y (6.7 h) than those who were more than 64 y (7.3 h). Those who were shift workers (6.5 h) reported less sleep than those who were regular day shift workers (6.8 h).

Short sleep duration causes fatigue, tiredness, excessive daytime sleepiness, and reduced neurocognitive function (Cappuccio et al., 2010b). Short sleep duration also exerts deleterious effects on changes in metabolic, endocrine, and immune pathways. It has been shown that short sleep duration may have long-term adverse health consequences and may result in obesity, diabetes, hypertension, cardiovascular disease, and premature death (Patel and Hu, 2008; Ayas et al., 2003; Gangwisch et al., 2006). Research has found that short sleep duration is associated with decreased leptin and increased ghrelin, which are related to increased appetite and increased BMI (Taheri et al., 2004). In several epidemiologic studies, short sleep duration is related to abnormalities in blood pressure, lipoproteins, glucose regulation, metabolic hormones, and obesity (Grandner and Youngstedt, 2011). In several prospective population studies, short duration of sleep is a significant predictor of death (Cappuccio et al., 2010b).

Occasional insomnia in people who usually sleep well is not abnormal; however, many people may have repetitive insomnia over a prolonged period, such as every night or every week, which may last from several months to several years (Ohayon, 2002). Those persons may have complaints of unsatisfactory sleep, including insufficient sleep, disrupted sleep, early morning awakenings, the feeling of being unrested after the habitual sleep period, and difficulty in initiating sleep. Difficulty in initiating sleep results in a long sleep latency, which is the length of time to transition from full wakefulness to sleep. Long sleep latency has been suggested as a mechanism to link the consequences of stress with immune suppression that in turn leads to chronic inflammation and progression to chronic disease states (Hall et al., 1998). Buysse et al. (1989) have suggested that complaints about sleep quality have become common and a considerable proportion of adults experience sleep quality disturbances, such as difficulty initiating asleep. Prinz et al. demonstrated that in women, but not men, higher cortisol (a marker of physiological stress) was associated with earlier time of arising (Prinz et al., 2000). A high level of cortisol has also been linked to partial sleep deprivation and insomnia (Spiegel et al., 1999).

Sleep outcomes and socioeconomic status (SES) characteristics

Researchers have found that sleep outcomes are linked to education, family income, and employment status (Adams et al., 2006; Bixler et al., 1979; Friedman et al., 2007; Grandner et al., 2010; Hale et al., 2005; Hall et al., 1999; Jean-Louis et al., 2001; Krueger & Friedman et al., 2009; Lauderadale et al., 2006; Moore et al., 2002; Phillips & Mannino, 2005; Sekine et al., 2005; Stamatakis,2007). However, there are no consistent conclusions. Most studies have found that SES were related to objective and subjective sleep quality and quantity, except Jean-Louis et al. (2001).

Tobacco exposure among children

In the US, cigarette smoking is the leading cause of death and preventable disease (CDC, 2014). In 2013, about 17.8% (42.1 million) American adults aged ≥ 18y were cigarettes smokers (CDC, 2014). About three in five (22 million) children aged 3-11y in the U.S. are secondhand/passive smokers, who are exposed to the smoke from the burning end of a cigarette and from the exhalation by active smokers (USDHHS, 2006). Tobacco smoke has at least 7,000 chemicals of which 70 are known toxic or carcinogenic chemicals, including formaldehyde, benzene, vinyl chloride, arsenic, ammonia, and hydrogen cyanide (USDHHS, 2014a; USDHHS, 2014b; USDHHS, 2010; USDHHS, 2006). Children who have passive smoke exposure are inhaling as many of these toxic and carcinogenic substances as those who are active smokers. Because of the development of children's body, infants and young children are most vulnerable to these poisons.

Tobacco exposure can cause serious health problems in children (USDHHS, 2006; USDHHS, 2014b). It has been noted that older children whose parent smoke get sick more often. Tobacco exposure is harmful to children's respiratory system and linked to higher risk of middle ear infections, bronchitis and pneumonia, coughing, wheezing, worse lung function, and asthma development (Quinto et al., 2013). Children who are secondhand smokers have lungs that grow less than those who do not breathe secondhand smoke. Tobacco exposure can trigger an asthma attack among children. Those with asthma whose parents are smokers have more frequent exacerbations and more severe symptoms than those whose parents are nonsmokers.

Socioeconomic characteristics of those who choose to smoke tobacco

Each year, tobacco use costs the U.S. $300 billion in medical expenses and $156 billion in lost productivity, including $5.6 billion due to secondhand smoke exposure (Xu et al., 2014). In 2014, about 264 billion cigarettes were sold in the U.S. and consumers spend as much as $10.56 per pack, which includes an average of 43.8% in federal and state excise taxes, on a pack of 20 cigarettes (Maxwell, 2015; Maxwell, 2014). It has been shown that men are more likely to currently smoke than women (CDC, 2014). Percentage of current cigarette smokers is lower among adults who have a graduate degree than those who have a lower education level, including high school, some college, or undergraduate college degree. Current cigarette smoking is also higher among persons who are living below the poverty threshold than those who are living at or above the threshold (CDC, 2014). Because most smokers in the U.S. are poor or near poor and families with at least one smoker spend 2%-20% of their income on tobacco, smoking can largely affect family financial resources (Efroymson et al., 2001; Stellman and Resnicow, 1997; Haustein, 2006).

Cutler-Triggs et al. (2008) observed that food insecurity was more prevalent and more severe in households with smokers. Among children, smoking was independently related to food insecurity and very low food security. Among low income households, about a third of children were living with a smoker, and in such households, a quarter of children and a third of adults experienced food insecurity some time during the year. Armour et al. (2001) also confirmed that cigarette consumption is related to increased food insecurity and smoking was more prevalent among food insecure families than food secure families. Low income families having a smoker purchased an average of 10 packs of cigarettes per week (cost $33.7). These families substituted cigarettes for food and adversely affected household food security.

Misclassification of self-reported smoking

With the increase of public health concerns on the consequences of both active and passive smoking, smoking has been treated as one of the undesirable health or social behaviors (Gorber et al., 2009). People may not be willing to admit to an undesirable social behavior so this behavior is prone to be underreported. Some studies have noted that using self-reported estimates may underestimate actual smoking prevalence (Lewis et al., 2003; Tyrpien et al., 2001). Surveys often measure the prevalence of tobacco smoking by collecting self-reported information, which typically rely on the participants being truthful at the interview (Gorber et al., 2009). The degree of misclassified smoking status depends on the population examined. For example, a population of pregnant women, who are perceived not to have prenatal smoking, may have a high rate of misclassification of their smoking status (Klebanoff et al., 2001).

To evaluate whether self-reported smoking status accurately reflect the actual status, some biochemical marker of tobacco, including nicotine, cotinine, carbon monoxide, carboxyhemoglobin, and thiocyanate, have been used in studies as indicators of actual smoking status (Caraballo et al., 2001). Cotinine, which is a major metabolite of nicotine, has been widely accepted and preferred as the most appropriate indicator of tobacco smoke exposure (Society for Research on Nicotine and Tobacco Subcommittee on Biochemical Verification et al., 2002). Unlike carboxyhemoglobin and thiocyanate, diet or pollution exposure does not impact cotinine (Gorber et al., 2009). It also has a longer half-life than nicotine, so cotinine is less dependent on temporal factors (Parker et al., 2002). Accordingly, cotinine is preferred as a biomarker for tobacco exposure whether that exposure is a result of the participant actively smoking and/or being exposed to secondhand smoke. Although cotinine can be measured in other body fluids, such as urine or saliva, serum cotinine has often been chosen to measure cotinine level for studies requiring a quantitative assessment (Patrick et al., 1994).

A nationally representative study of U.S. children without reported smoke exposure has found that significant predictors of increased cotinine levels included black race, young age, low number of rooms in the home, and low family poverty index (Mannino et al., 2001). Identifying factors that contribute to misclassification of self-reported smokers and nonsmokers could allow more accurate estimates of smoking prevalence.

Based on previous literature, which urges a better understanding of the health and behavior status of food insecure persons in the U.S., several hypotheses were proposed and determined in this dissertation.

Statement of research objectives

The specific questions for the first study, conducted with adult participants, were to:

1) Determine the association between household food security status and sleep duration.
2) Determine the association between household food security status and sleep latency (length of time to transition from full wakefulness to sleep).
3) Determine the association between household food security status and sleep complaints reported to a health care professional.
4) Determine whether the association between household food security status and any of the sleep outcomes is modified by sex.

The specific objectives for the second study, conducted with children participants, were to:

1) Estimate the likelihood of asthma among children living in food insecure households compared to children in food secure households.
2) Determine whether the association between household food security status and children's asthma is modified by their exposure to tobacco.

The specific questions for the third study, conducted with children participants, were to:

1) Estimate the extent of misclassification of children's tobacco exposure.
2) Determine the socioeconomic and demographic predictors of the misclassification of children's tobacco exposure.

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Chapter 3 Association between Food Insecurity and Poor Sleep Outcomes among Adults

Abstract

Background. Although food insecure (FI) adults are at risk for chronic conditions, little research attention has been given to their health behaviors, such as sleep.

Objective. We examined the associations between adult food security status and sleep duration, sleep latency, and sleep complaints reported to a health care professional.

Methods. Our population-based sample included 5,637 men and 5,264 women (≥ 22 y) who participated in the NHANES 2005-2010. Food security status was assessed with USDA's 10-item adult Food Security Survey Module. Self-reported information regarding sleep duration, sleep latency, and sleep complaints to a health care professional were used as sleep outcomes. Multiple linear, stratified by sex, and logistic regression models were used to estimate the association between food security status and the three sleep outcomes.

Results. Very low food secure women reported significantly shorter sleep duration than fully food secure women (difference: -30±5.2 min; *P*<0.01); however, no relationship regarding sleep duration was observed among men. Among men those who were marginally food secure (4±1.1 min), low food secure (4±1.7 min), and very low food secure (5±1.8 min) reported significantly longer sleep latency than fully food secure men (*P*<0.05), but no association regarding sleep latency was observed among women. The divergent patterns in sleep duration and latency were likely due to our reference groups reporting undesirable sleep outcomes; Fully food secure men reported inadequate sleep and fully food secure women reported long sleep latency. Among both men and women, marginally food secure (OR 1.64, 95% CI 1.24-2.16), low food secure (OR 1.63, 95% CI 1.16-2.30), and very low food secure (OR 1.99, 95% CI 1.36-2.92) participants were more likely to report sleep complaints than their fully food secure counterparts ($P<0.05$). *Conclusions*. Poor sleep quantity and quality may predispose food insecure adults to adverse health outcomes.

Introduction

Findings from the 2012 Current Population Survey indicate that in the United States 14.1% of adults were food insecure and of those 5.3% were characterized as very low food secure (Coleman-Jensen et al., 2013). Food insecurity has been widely recognized as a serious public health problem, as numerous studies focusing on U.S. adult populations have demonstrated that food insecurity is associated with obesity (Tayie and Zizza, 2009; Franklin et al., 2012), diabetes (Seligman et al., 2007; Vozoris et al., 2003; Ding et al., 2014), hypertension (Vozoris et al., 2003; Seligman et al., 2010; Parker et al., 2010), hyperlipidemia (Seligman et al., 2010; Tayie and Zizza, 2009; Dixon et al., 2001), and heart disease (Vozoris et al., 2003). Food insecure adults are also more likely to experience poorer mental health (Casey et al., 2004; Gundersen et al., 2003; Laraia et al., 2006; Stuff et al., 2004) and depression (Vozoris et al., 2003; Whitaker,2006; Beydoun and Wang, 2010) than their food secure counterparts. Although food insecure adults are recognized as a vulnerable population, the intricate causal mechanisms by which food insecurity predisposes one to adverse health outcomes have not been adequately identified.

Modifiable, lifestyle-related health behaviors, such as poor diet quality, smoking, physical inactivity and inadequate sleep, have been identified as risk factors for many chronic conditions, as well as premature mortality (Meng et al., 1999; Pronk et al., 2004). Researchers have hypothesized that shifts in dietary quantity and quality associated with food insecurity (Laraia et al., 2006; Zizza et al., 2008) may promote an inflammatory state in the body, as well as an increased susceptibility to infection (Gowda et al., 2012). Few studies have assessed the lifestyle-related behaviors, other than diet quality, of food insecure populations (Laraia, 2013).

Sleep is as an ancestral and primitive behavior predicted by almost everyone on a daily basis (Cappuccio et al., 2010a). Due to longer working hours, more shift-work, and the 24-7 availability of food and recreational activities, the average number of hours of sleep has declined over the past century (Naional Sleep Foundation et al., 2002; Akerstedt and Nilsson, 2003). Buysse et al. (1989) have suggested that complaints about sleep quality have become common and a considerable proportion of adults experience sleep quality disturbances, such as difficulty initiating asleep (Buysse et al., 1989). Difficulty initiating sleep has been suggested as a mechanism to link the consequences of stress with immune suppression, which in turn leads to chronic inflammation and progression to chronic disease states (Hall et al., 1998). Because sleep has been recognized as an important determinant of health and well-being, sleep hygiene recommendations have been developed by several health organizations (Naional Sleep Foundation, 2002; University of Maryland Medical Center, 2014; American Academy of Sleep Medicine, 2014).

As with food insecurity, poor sleep outcomes have been linked to chronic conditions, such as obesity (Gangwisch et al., 2005; Knutson and Cauter, 2008; Marshall et al., 2008), diabetes (Cappccio et al., 2010; Gangwisch et al., 2007; Morselli et al., 2010; Yaggi et al., 2006; Zizi et al., 2012), heart disease (Meisinger et al., 2007; Wolk et al., 2005), and hypertension (Gangwisch et al., 2006; Tochikubo,1996). Although the chronic conditions associated with food insecurity and inadequate sleep are similar, we are not aware of any reports that have examined the relationship between food insecurity and any measure of sleep. Accordingly, our purpose was to estimate the association between food insecurity and several sleep outcomes. We hypothesized that food insecure adults have poorer sleep outcomes than food secure adults.

Using a nationally representative sample, we evaluated the relationship between food security status and the following sleep outcomes: sleep duration, sleep latency (length of time to transition from full wakefulness to sleep), and sleep complaints reported to a health care professional. The association between food security status and health outcomes has been shown to vary by sex (Tayie and Zizza, 2009; Ding et al., 2014; Zizza et al., 2008). For example, food insecurity has been linked to obesity and overweight among adult women, but not among men. Therefore the possibility that the relationship between food security status and the three sleep outcomes is moderated by sex was also examined. Investigating the association between food insecurity and sleep quantity and quality may expand our understanding of the potential pathways through which food insecurity is associated with adverse health outcomes.

Methods

Sample. The NHANES of the National Center for Health Statistics are cross-sectional, nationally representative health and nutrition surveys of the noninstitutionalized U.S. civilian population. The NHANES are complex multistage probability samples and details regarding the recruitment and survey design of these samples have been published elsewhere (CDC, 2013). We combined data from the 2005-06, 2007-08, and 2009-10 waves of NHANES (men n = 15,401; women n = 15,633).

Adults aged ≥ 22 y (*n* = 15,961) were included in the analytical sample, so we could compare population adjusted means to age-based Healthy People 2020 recommendations (USDHHS, 2013). We excluded pregnant (*n* = 417) and breast feeding women (*n* = 93) because they are likely to have disrupted sleep patterns. We excluded participants who reported taking medication for insomnia, sleep apnea, sleep automatism, sleep walking disorder, and shift-work sleep disorder (*n* = 1,194). Participants who did not have complete information on food security status (*n* = 152) and sleep outcomes (*n* = 20) were excluded. We further excluded participants (*n* =953) who reported being diagnosed with a sleep disorder. Our analytical sample then included participants with complete information on age, poverty income ratio (PIR) (missing *n* = 1,061), BMI (missing *n* = 591), mental health (missing *n* = 511), household size, race/ethnicity, education level (missing *n* = 9), marital status (missing *n* = 7), work schedule (missing *n* = 3), general health condition (missing *n* = 4), smoking status (missing *n* = 5), alcohol consumption (missing *n* = 20), and menopause status (only for women) (missing *n* = 20). The analytic sample included 5,637 men and 5,264 women for the analysis of sleep duration and sleep complaints. The analysis of sleep latency was based on the 2005-06 and 2007-08 waves of NHANES because the 2009-10 wave did not include this item. The analytic sample for sleep latency included 3,617 men and 3,363 women.

Details regarding NHANES participants' consents have been published elsewhere (CDC, 2014a; CDC, 2014b; CDC, 2014c). The protocol for this study was approved by the Institutional Review Board, Office of Human Subjects Research, Auburn University.

Food security status. NHANES 2005-10 included the Food Security Survey Module, which is a well-validated questionnaire that measures the presence of food insecurity at the household level during the past 12 months (Bickel et al., 2000). We used participants' responses to the 10 household adult items in the 18-item scale, because the remaining 8 items are specific for children (CDC, 2014d). Thus, we considered a participant to be fully food secure if 0 items in the scale were answered affirmatively and marginally food secure if 1-2 items were affirmative. We further classified food insecure participants as low food secure if 3-5 items were affirmative and very low food secure if 6-10 items were affirmative. Low and very low food security classifications were referred to as food insecurity (Bickel et al., 2000).

Sleep outcomes. Questions on sleep were asked during the household interview using the Computer-Assisted Personal Interview system (CDC, 2014d). We used questions regarding self-reported sleep duration, sleep latency and sleep complaints as outcome variables. Participants were asked how many hours of sleep they usually got at night on weekdays or workdays. Participants' answers ranged from 1-11 h and those who reported 12 h or more were coded as 12 h during the interview (CDC, 2014d). Inadequate sleep was classified as those reporting < 7 h of sleep per night (USDHHS, 2013).

Evidence supports an association between both short and long duration of habitual sleep with several chronic conditions and premature mortality (Cappuccio et al., 2010b). Our analyses on long sleep duration (≥ 9 h) was limited by sample size (marginal food secure men n=35, low food secure men n=36, very low food secure men n=26, marginal food secure women n=35, low food secure women n=33, very low food secure women n=23). Thus, we excluded those who had long sleep duration in the prevalence estimates and the analyses of sleep duration. We also estimated all our associations with participants reporting long sleep duration and we observed similar results.

In the 2005-08 NHANES, participants were asked how long it usually took to fall asleep at bedtime (sleep latency). Answers ranged from 0 to 59 min and those who reported 60 min or more were coded as 60 min during the interview (CDC, 2014d). In the 2005-10 NHANES, participants also reported whether they had ever told a doctor or health care professional that they were having trouble sleeping (sleep complaints).

Control variables. We used participants' age at the time of their screening interview, household family PIR, measured BMI, and household size as continuous control variables in our analyses. Other variables were used as indicator control variables, including race/ethnicity, education level, marital status, work schedule, mental health, general health condition, smoking status, alcohol consumption, and menopause status (only for women). Mental health was assessed by participants' response to the item; "for how many days during the past 30 days was your mental health not good." We classified mental health into two categories: 0 day and ≥ 1 day. We grouped race/ethnicity as non-Hispanic White, non-Hispanic Black, Mexican-American and other races, including other Hispanic and multi-racial. Education levels were collapsed into two categories: < high school and ≥ high school degree (or equivalent). Marital status was classified into two categories: living with partner (those who were married or were living with a partner), and living without partner (those who were widowed, divorced, separated, or never married). Work schedule was grouped into three categories: regular daytime schedule, shift schedules (including evening, night, and rotating shift), and not working. Self-reported general health condition had two levels: excellent to good and fair to poor. Smoking status was classified into three categories: non-smoker, former smoker, and current smoker. Alcohol consumption was classified based on the average number of alcoholic drinks consumed per day; non-drinker, moderate drinker (up to one drink per day for women and two drinks per day for men), and heavy drinker (more than one drink per day for women and more than two drinks per day for men) (USDA, 2010). We also considered menopause status in our analyses of women. This variable was dichotomized to menopause/ hysterectomy/ medical treatments and having menstrual period in the past 12 months.

Statistical analysis. As indicated by NCHS (CDC, 2013), the sampling weights and sample design variables from the 3 survey rounds (2 rounds for sleep latency) were used to account for the stratification and clustering of observations in the NHANES. All values were considered significant at $P \leq 0.05$. Associations across levels of food security were tested by χ^2-tests of independence for categorical variables and linear regression models for continuous variables.

We used multiple linear regression models to examine the association between food security status and self-reported hours for sleep duration and minutes for sleep latency, whereas we used logistic regression models to examine the association between food security status and sleep complaints.

Several model specifications, such as age alone, age and socioeconomic status (SES) variables, and a full model of age, SES, and health variables, were used in our regression analyses. Because our results were robust for controlling SES and for controlling SES with health variables, we present two model specifications; Model 1 controlling for age and Model 2 including all control variables. Continuous variables were age, PIR, BMI, and household size. Indicator variables included race/ethnicity, education level, marital status, and work schedule, poor mental health, general health condition, smoking status, alcohol consumption, and menopause status (only for women). Reference groups for each variable used in our multiple linear and logistic regression models are indicated in Table 3-1. Analyses were stratified by sex because we found significant interaction terms (sex and food security status) in the full model analyses of sleep duration and sleep latency ($P<0.05$). In our stratified analysis for women, fully food secure women were considered the referent group, while in our stratified analysis, for men, fully food secure men were the referent group. For sleep duration, we examined a model in which fully food secure women were the common referent for all sex and food security categories. We also examined a model in which fully food secure men were the common referent for sleep latency. Using a common referent analysis, we statistically tested whether our reference groups were reporting short sleep duration and long sleep latency. Reference groups reporting poor outcomes can be an underlining reason for finding no association. To account for possible confounding by income, we conducted additional analyses and restricted the sample to low income participants. A 185% PIR was used as cut-off for low income, because it is the upper bound for several Food and Nutrition Service programs and often used in analyses (USDA, 2014).

Results

Table 3-1 presents socio-demographic and health-related characteristics by food security status for men and women. Differences across levels of food security for men and women were found for every characteristic: age, PIR, BMI, household size, race/ethnicity, education level, marital status, work schedule, poor mental health, general health condition, smoking status, and alcohol consumption as well as menopause status among women. The prevalence of inadequate sleep duration is presented by food security status for men and women in Figure 1. Those reporting inadequate sleep ranged from 38% in fully food secure to 52% in very low food secure men. The percentage ranged from 33% in fully food secure to 61% in very low food secure women. In a bivariate analysis, food security status was associated with inadequate sleep among both men and women (P<0.05).

The adjusted mean values for sleep duration are presented in Table 3-2. Very low food secure women reported significantly shorter sleep duration than fully food secure women in both model specifications (P<0.01). Marginally food secure and low food secure women also reported shorter sleep duration than fully food secure women in Model 1, but the association was attenuated and no longer significant after further adjustment. On average, very low food secure women reported sleeping half an hour less than fully food secure women (-30±5.2 min; P<0.01), while controlling for all variables. Among men, differences in sleep duration were not observed after adjustment. With the common referent analysis, fully food secure, low food secure men, and low food secure, very low food secure women reported shorter sleep duration than fully food secure women (Supplemental Tables 3-1).

Table 3-3 presents the adjusted mean values for sleep latency. Among men those who were marginally, low, and very low food secure reported significantly longer sleep latency than fully food secure men in both model specifications (P<0.05). On average, marginally, low, and very low food secure men reported 4-5 min more than fully food secure men, while controlling for all variables. Among women those who were marginally food secure, low food secure and very low food secure reported longer sleep latency than fully food secure women in Model 1, but the association was attenuated and no longer significant after further adjustment. With the common referent analysis, marginally food secure, low food secure, and very low food secure men, as well as fully food secure, low food secure, and very low food secure women reported longer sleep latency than fully food secure men (Supplemental Tables 3-2).

Table 3-4 presents the adjusted odds ratios for sleep complaints. Compared to fully food secure adults, marginally food secure and low food secure adults were approximately 60% more likely and very low food secure adults were twice as likely to report sleep complaints (P<0.05).

When the sample was restricted to those with PIR < 185%, similar results for sleep duration, sleep latency and sleep complaints were found in both model specifications (Supplemental Tables 3-5). Our results were again robust in that excluding participants with sleep disorders did not change any of our reported findings.

Discussion

To our knowledge, our study is the first to demonstrate a link between food insecurity and habitual short sleep duration and long sleep latency, as well as frequent sleep complaints to a health care professional. Although the presence of a relationship depended on participants' sex, two different conclusions were reached regarding the relationships between food insecurity and sleep duration and latency. Among women, those who were very low food secure were associated with sleeping less, however, no relationship was found among men. Conversely, among men food insecurity was associated with prolonged sleep latency yet among women no association was observed. Based on the common referent analysis, these divergent patterns were likely due to our reference groups reporting undesirable sleep outcomes; fully food secure men reported inadequate sleep and fully food secure women reported long sleep latency. While the results for sleep duration and latency were divergent, we found both men and women in food insecure households were more likely to report sleep complaints to a health care professional.

Comparisons between the results of our study and previous studies are difficult because no other studies have examined the relationship between food insecurity and sleep. However, there is a large body of literature regarding the relationship between income and sleep outcomes including sleep duration, sleep latency, and sleep complaints. Researchers found that low income was linked to short sleep duration (Stamatakis et al., 2007) and more frequent sleep complaints (Grandner et al., 2010). Higher income was related to better sleep quality (Lauderdale et al., 2006), greater sleep efficiency, and shorter sleep latency (Lauderdale et al., 2006; Friedman et al., 2007). All of the SES studies support our results that food insecure, caused primarily by a lack of resources, may have an effect on adults' quality and quantity of sleep. While these studies support this relationship, it is still imperative to examine the relationship between food insecurity and sleep because there is not a one-to-one correspondence between income and food security status (Rose, 1999). Even after we controlled for PIR and restricted the data to only those who had low income in our models, the associations between food security status and the three sleep outcomes remained.

The mechanisms that underlie the relationship between food security status and sleep have obviously not been established, however there are several possibilities. One possibility is that food insecurity may work through poor mental health (Stuff et al., 2004). Studies have linked food insecurity to depression (Heflin et al., 2005; Hadley and Patil, 2006; Tsai et al., 2012; German et al., 2011), anxiety (Hadley and Patil, 2006) and stress (Laraia et al., 2006; Tsai et al., 2012; Hamelin et al., 1999; Jilcott et al., 2011). Using a longitudinal design, researchers observed that changes in food insufficiency status are associated with changes in depression status among women (Rose et al., 1999). In rural Tanzania, Hadley and Patil (2006) found that food insecurity increases the risk of anxiety and depression. Whitaker and colleagues found a relationship between higher levels of food insecurity and higher levels of maternal anxiety (Whitaker et al., 2006). Several groups have linked food insecurity to both acute and chronic stress (Laraia et al., 2006; Hamelin et al., 1999; Jilcott et al., 2011). Researchers have reported an association among depression, stress and sleep (Akerstedt and Nilsson, 2003; Hall et al., 1998; Tsuno et al., 2005). Although we included mental health status in our analyses, it is possible that mental health problems in those marginally food secure, low food secure and very low food secure adults could still potentially result in poor sleep outcomes. Because mental and physical health might in fact be intermediaries in the associations between food insecurity and poor sleep outcomes, this might represent statistical overadjustment. Another possible mechanism might be that food insecure adults may have diets deficient in nutrients, such as B12, folic acid (Kirkpatrick et al., 2008), which could influence mood and immune functions (Tamura et al., 1999; Benton and Donohoe, 1999) and that in turn may have an effect on their sleep.

Our results provide insights regarding the potential health benefits of participating in food and nutrition assistance programs. The largest and best known federal food assistance program is the Supplemental Nutrition Assistance Program (SNAP), formerly the Food Stamp Program, which has a well-established framework aimed at reducing food insecurity in the U.S. (Nord and Golla, 2009). Although analyzing the impact of SNAP on household food security is complicated by self-selection problems, where food insecurity is a primary driver of families seeking assistance, receipt of SNAP benefits has been shown to lower the prevalence and severity of food insecurity (Mykerezi and Mills, 2010; Nord and Golla, 2009; Ratcliffe et al., 2011; Kreider et al., 2012; DePolt et al., 2009). To the extent to which SNAP can reduce food insecurity and, hence, improve sleep hygiene and encourage healthy diets, it may have the potential to prevent the development of chronic conditions, as well as premature mortality (Kreider et al., 2012; Gundersen et al., 2011). Future studies should examine the potential impact of SNAP on sleep hygiene.

The relationships between food insecurity and sleep duration we observed among women was expected because other studies have found sex differentials in the health consequences of food insecurity (Tayie and Zizza, 2009; Ding et al., 2014; Tayie and Zizza, 2009). Prinz et al. (2000) demonstrated that in women, but not men, higher cortisol (a marker of physiological stress) was associated with earlier time of arising (Prinz et al., 2000). A high level of cortisol has also been linked to partial sleep deprivation and insomnia (Spiegel et al., 1999). We know of no literature that details the mechanisms for observing differences in our food insecurity and sleep latency relationships for men and women.

The finding regarding complaints to a health care professional was expected among women. Women have more frequent contacts with the medical system, receive more physician time, and get more detailed answers to their medical questions than men (Courtenay, 2000). Other researchers have suggested that men are less likely to recognize signs and symptoms and delay seeking medical help because they perceive less vulnerability than women (Nicholas, 2000). For example, we have previously reported that men with food insecurity were less aware than women with food insecurity of their health risk for diabetes (Ding et al., 2014). It has been suggested that men respond differently to stressors such as poverty than women by embracing poor coping strategies, such as alcohol consumption and smoking that lead to high mortality rates. Our results suggest that among men, food insecurity may not prevent them from seeking medical attention regarding sleep concerns.

There were some limitations to our outcome measures. Sleep duration and latency were measured according to participants' self-report, which was potentially subject to recall bias. Objective sleep recording using wrist actigraphy may provide more accurate measurements than self-reported sleep measurement. However, self-reported and measured sleep duration have been shown to be moderately correlated (Lauderdale et al., 2008). Although actigraphy provides an adequately accurate measure of duration, Lauderdale et al. suggested that it leaves important sleep characteristics unmeasured. Another limitation is that self-reported sleep duration and latency were based on participants' responses of "usual" sleep without a specific time period, whereas food security status was assessed regarding the past 12 months. Thirdly, the item regarding sleep complaints was measured by one general question without further details, such as whether the complaint was for insomnia or waking up during the night. Fourthly, although we controlled for demographic, social-economic, and health-related variables in our analyses, there remains several environmental factors, such as noise and light level in participants' sleep environment that we could not include. Fifthly, another limitation involves using regression models to estimate the association between food security status and our three sleep outcomes. When using regression models, we assume food insecurity is exogenous and not correlated with the error term in the regression model. Although, there might be bias due to this assumption, Gundersen and Kreider (2009) have stated that results regarding the impact of food insecurity on health are more likely to be underestimated than overestimated. Lastly, the study is limited by the cross-sectional nature of NHANES, which does not allow us to determine the causal relationship between food insecurity and the three sleep outcomes. Reverse causation is possible in that sleep problems may lead to lower job performance and lower income and these in turn may lead to food insecurity.

In conclusion, results from this study suggest that poor sleep quantity and quality may predispose food insecure adults to adverse health outcomes. Participation in food and nutrition assistance programs may alleviate food insecure, which in turn may have the potential to improve diet quality and sleep hygiene. In addition to encouraging participation in food and nutrition assistance programs, health promotion efforts for food insecure populations should incorporate advice regarding sleep hygiene.

TABLE 3-1 Characteristics of adults, ≥22 y, by food security status[1]

Food security status	Men (*n* = 5,637) Full (*n* = 4,244)	Men Marginal (*n* = 579)	Men Low (*n* = 488)	Men Very low (*n* = 326)	Women (*n* = 5,264) Full (*n* = 3,894)	Women Marginal (*n* = 608)	Women Low (*n* = 477)	Women Very low (*n* = 285)
	Mean ± SE							
Age, *y*	47.7±0.5	40.5±0.7	40.6±0.7	39.8±0.9	49.5±0.4	43.5±0.8	42.0±0.7	42.5±1.2
PIR[2]	3.5±0.0	2.0±0.1	1.6±0.1	1.4±0.1	3.4±0.0	1.9±0.1	1.5±0.1	1.3±0.1
BMI, kg/m^2	28.5±0.1	28.7±0.4	27.7±0.3	27.6±0.5	28.1±0.2	30.5±0.3	30.5±0.5	30.1±0.6
Household size	2.8±0.0	3.8 ±0.1	3.6±0.1	3.3±0.2	2.8±0.0	3.5±0.1	3.5±0.1	3.3±0.2
	Percent							
Race/Ethnicity								
Non-Hispanic White[3]	77	46	43	45	77	49	43	54
Non-Hispanic Black	8	16	18	22	10	21	22	20
Mexican American	6	23	24	17	5	17	18	12
Other races[4]	9	14	14	17	8	12	17	14
Education level								
≥ High school[3]	85	67	55	56	86	72	64	69
< High school	15	33	45	44	14	28	36	31
Marital status								
Living with partner[3]	73	69	61	53	65	52	47	41
Living without partner	27	31	39	47	35	48	53	59
Work schedule								
Regular daytime schedule[3]	58	56	46	46	50	42	40	35
Shift schedule	18	20	20	18	12	16	16	13
Not working	24	23	34	36	37	41	44	52
Poor mental health, *d*								
0[3]	71	65	60	41	58	46	47	31
≥ 1	29	35	40	59	42	54	53	69
General health condition								
Excellent to good[3]	88	76	70	69	88	77	71	61
Fair to poor	12	24	30	31	12	23	29	39

Smoking status								
Non smoker[3]	48	43	40	33	62	55	52	40
Former smoker	30	22	17	18	22	18	16	12
Current smoker	21	35	44	49	16	28	32	47
Alcohol consumption								
Non-drinker[3]	21	23	23	24	30	37	36	38
Moderate drinker	45	25	27	28	32	24	25	19
Heavy drinker	35	52	49	48	38	39	40	44
Menopause status								
No[3]			NA		51	62	63	62
Yes			NA		49	38	37	38

[1] NHANES 2005-2010 were used in the analysis. All values were weighted and design corrections were applied to the analysis as directed by the National Center for Health Statistics (CDC, 2013). Column percentages do not always add up to 100% because of rounding. Food security status was significantly different for every continuous characteristic by linear regression models and every categorical characteristic by χ^2-tests of independence among both men and women. Significant *P*-values <0.05.

[2] Poverty income ratio was calculated by dividing family income by the annual poverty threshold provided by U.S. Census Bureau.

[3] Reference group in linear and logistic regression analyses.

[4] Other races includes other Hispanic and multi-racial.

TABLE 3-2 Predicted and average difference in sleep duration across food security status among adults[1]

Sex Food security status	Model 1			Model 2		
	Predicted sleep, *h*	*β* ± SE, *min*	*P*	Predicted sleep, *h*	*β* ± SE, *min*	*P*
Men (*n* = 5,283)						
Full (*n* = 3,987)	6.7	Reference	-	6.7	Reference	-
Marginal (*n* = 544)	6.6	-4±3.6	0.29	6.7	0±3.9	1.0
Low (*n* = 452)	6.6	-8±5.2	0.10	6.6	-4±5.5	0.43
Very low (*n* = 300)	6.4	-20±6.9	<0.01	6.5	-12±7.3	0.11
Women (*n* = 4,854)						
Full (*n* = 3,575)	6.8	Reference	-	6.7	Reference	-
Marginal (*n* = 573)	6.6	-13±3.9	<0.01	6.7	-3±3.6	0.39
Low (*n* = 444)	6.4	-24±5.3	<0.01	6.6	-10±5.2	0.06
Very low (*n* = 262)	6.0	-48±4.9	<0.01	6.2	-30±5.2	<0.01

[1] NHANES 2005-2010 were used in the analysis. Predicted sleep duration in hours and *β* coefficients in minutes were from linear regression models adjusted for different control variables in the two models. Participants who had long sleep duration (≥9 h) were excluded in this analysis. Model 1 was adjusted for age, and Model 2 included age and was further adjusted for poverty income ratio, BMI, household size, race/ethnicity, education level, marital status, work schedule, poor mental health, general health condition, smoking status, alcohol consumption, and menopause status (only for women). All values were weighted and design corrections were applied to the analysis as directed by the National Center for Health Statistics (CDC, 2013).

TABLE 3-3 Predicted and average difference in sleep latency across food security status among adults [1]

Sex Food security status	Model 1			Model 2		
	Predicted sleep latency, *min*	$\beta \pm$ SE, *min*	*P*	Predicted sleep latency, *min*	$\beta \pm$ SE, *min*	*P*
Men (*n* = 3,617)						
Full (*n* = 2,814)	18	Reference	-	19	Reference	-
Marginal (*n* = 345)	24	6±1.0	<0.01	24	4±1.1	<0.01
Low (*n* = 296)	25	7±1.7	<0.01	24	4±1.7	0.03
Very low (*n* = 162)	28	10±2.0	<0.01	25	5±1.8	<0.01
Women (*n* = 3,363)						
Full (*n* = 2,562)	21	Reference	-	23	Reference	-
Marginal (*n* = 377)	25	3±1.5	0.03	23	0±1.7	0.99
Low (*n* = 289)	27	6±1.7	<0.01	25	1±1.6	0.37
Very low (*n* = 135)	31	9±2.3	<0.01	27	4±2.4	0.14

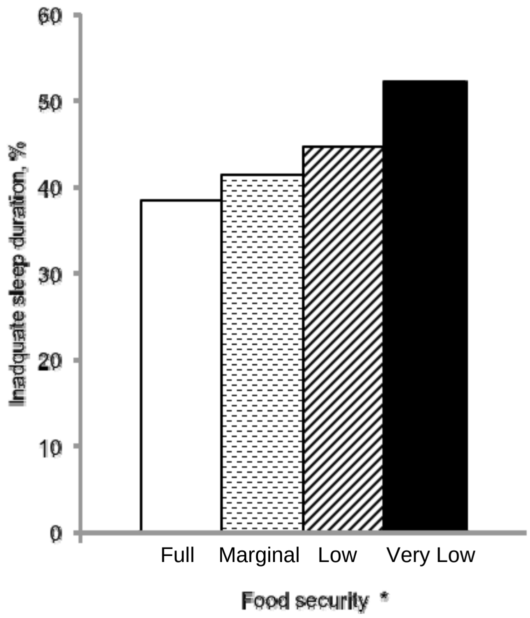
[1] NHANES 2005-2008 were used in the analysis. Predicted sleep latency and β coefficients in minutes were from linear regression models adjusted for different control variables in the two models. Model 1 was adjusted for age, and Model 2 included age and was further adjusted for poverty income ratio, BMI, household size, race/ethnicity, education level, marital status, work schedule, poor mental health, general health condition, smoking status, alcohol consumption, and menopause status (only for women). All values were weighted and design corrections were applied to the analysis as directed by the National Center for Health Statistics (CDC, 2013).

TABLE 3-4 Association between food security status and sleep complaints among adults[1]

Food security status	Adjusted OR (95% CI) Model 1	Model 2
Men and women (*n* = 10,901)		
Full (*n* = 8,138)	Reference	Reference
Marginal (*n* = 1,187)	1.56 (1.25-1.96)	1.64(1.24-2.16)
Low (*n* = 965)	1.47(1.11-1.94)	1.63(1.16-2.30)
Very low (*n* = 611)	2.03(1.57-2.63)	1.99(1.36-2.92)

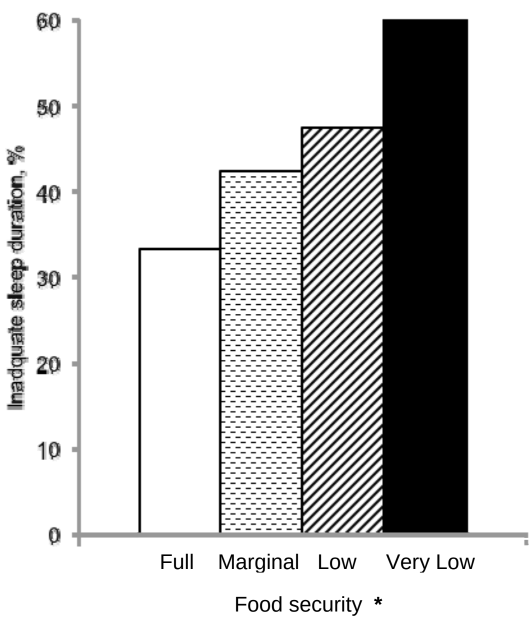
[1] NHANES 2005-2010 were used in the analysis. Adjusted OR were from logistic regression models adjusted for different control variables in the two models. Model 1 was adjusted for age, and Model 2 included age and was further adjusted for poverty income ratio, BMI, household size, race/ethnicity, education level, marital status, work schedule, poor mental health, general health condition, smoking status, alcohol consumption, and menopause status (only for women). All values were weighted and design corrections were applied to the analysis as directed by the National Center for Health Statistics (CDC, 2013).
OR: Odds Ratio

A



60
50
40
30
20
10
0
Inadquate sleep duration, %
Full
Marginal
Low
Very Low
Food security *

B



60
50
40
30
20
10
0
Inadquate sleep duration, %
Full
Marginal
Low
Very Low
Food security *

FIGURE 1 Prevalence of inadequate sleep duration among men (A) (*n* = 5,283; Fully food secure *n* = 3,987; Marginally food secure *n* = 544; Low food secure *n* = 452; Very low food secure *n* = 300) and women (B) (*n* = 4,854; Fully food secure *n* = 3,575; Marginally food secure *n* = 573; Low food secure *n* = 444; Very low food secure *n* = 262) by food security status. NHANES 2005-2010 were used in the analysis. Inadequate sleep (< 7 h of sleep per night) was based on Healthy People 2020 sleep recommendations (National Sleep Foundation, 2002). Participants who had long sleep duration (≥9 h) were excluded in this analysis. All values were weighted and design corrections were applied to the analysis as directed by the National Center for Health Statistics (CDC, 2013). Inadequate sleep was not independent of food security status (χ^2-tests of independence).
* $P < 0.05$

SUPPLEMENTAL TABLE 3-1 Predicted and average difference in sleep duration across all sex and food security categories with fully food secure women as the common referent[1]

Sex Food security status	Model 1 Predicted sleep, *h*	β ± SE, *min*	*P*	Model 2 Predicted sleep, *h*	β ± SE, *min*	*P*
Women						
Full (*n* = 3,575)	6.8	Reference	-	6.7	Reference	-
Marginal (*n* = 573)	6.6	-12±3.9	<0.01	6.7	-3±3.9	0.45
Low (*n* = 444)	6.5	-23±5.3	<0.01	6.6	-10±5.0	0.04
Very low (*n* = 262)	6.0	-48±5.0	<0.01	6.2	-30±4.7	<0.01
Men						
Full (*n* = 3,987)	6.7	-8±2.0	<0.01	6.6	-8±2.1	<0.01
Marginal (*n* = 544)	6.6	-12±3.5	<0.01	6.6	-6±3.9	0.12
Low (*n* = 452)	6.5	-17±5.0	<0.01	6.6	-9±5.3	0.09
Very low (*n* = 300)	6.4	-28±6.7	<0.01	6.5	-17±6.8	0.02

[1] NHANES 2005-2010 were used in the analysis. Predicted sleep duration in hours and β coefficients in minutes were from linear regression models adjusted for different control variables in the two models. Participants who had long sleep duration (≥9 h) were excluded in this analysis. Model 1 was adjusted for age, and Model 2 included age and was further adjusted for poverty income ratio, BMI, household size, race/ethnicity, education level, marital status, work schedule, poor mental health, general health condition, smoking status, and alcohol consumption. All values were weighted and design corrections were applied to the analysis as directed by the National Center for Health Statistics (CDC, 2013).

SUPPLEMENTAL TABLE 3-2 Predicted and average difference in sleep latency across all sex and food security categories with fully food secure men as the common referent [1]

Sex Food security status	Model 1 Predicted sleep latency, *min*	Model 1 β ± SE, *min*	Model 1 *P*	Model 2 Predicted sleep latency, *min*	Model 2 β ± SE, *min*	Model 2 *P*
Men						
Full (*n* = 2,814)	18	Reference	-	20	Reference	-
Marginal (*n* = 345)	24	7±1.0	<0.01	24	4±1.0	<0.01
Low (*n* = 296)	25	8±1.8	<0.01	24	4±1.7	0.03
Very low (*n* = 162)	28	10±2.0	<0.01	25	5±1.9	0.02
Women						
Full (*n* = 2,562)	21	4±0.7	<0.01	23	3±0.7	<0.01
Marginal (*n* = 377)	25	7±1.5	<0.01	23	3±1.6	0.05
Low (*n* = 289)	27	9±1.5	<0.01	24	5±1.5	<0.01
Very low (*n* = 135)	31	13±2.2	<0.01	26	6±2.1	<0.01

[1] NHANES 2005-2008 were used in the analysis. Predicted sleep latency and β coefficients in minutes were from linear regression models adjusted for different control variables in the two models. Model 1 was adjusted for age, and Model 2 included age and was further adjusted for poverty income ratio, BMI, household size, race/ethnicity, education level, marital status, work schedule, poor mental health, general health condition, smoking status, and alcohol consumption. All values were weighted and design corrections were applied to the analysis as directed by the National Center for Health Statistics (CDC, 2013).

SUPPLEMENTAL TABLE 3-3 Predicted and average difference in sleep duration across food security status among low-income adults[1]

Sex / Food security status	Model 1			Model 2		
	Predicted sleep, *h*	*β* ± SE, *min*	*P*	Predicted sleep, *h*	*β* ± SE, *min*	*P*
Men (*n* =2,126)						
Full (*n* = 1,186)	6.7	Reference	-	6.7	Reference	-
Marginal (*n* = 3,54)	6.6	-7±4.8	0.18	6.6	-6±4.3	0.17
Low (*n* = 347)	6.5	-11±5.2	0.05	6.6	-8±5.4	0.15
Very low (*n* = 239)	6.5	-15±6.7	0.03	6.6	-8±6.9	0.27
Women (*n* =2,081)						
Full (*n* = 1,094)	6.7	Reference	-	6.6	Reference	-
Marginally (*n* = 398)	6.7	-1±4.9	0.83	6.7	-2±5.0	0.70
Low (*n* = 368)	6.4	-16±5.4	<0.01	6.5	-10±5.3	0.07
Very low (*n* = 221)	6.0	-39±6.1	<0.01	6.2	-25±6.3	<0.01

[1] NHANES 2005-2010 were used in the analysis. Predicted sleep duration in hours and *β* coefficients in minutes were from linear regression models adjusted for different control variables in the two models. Participants who had long sleep duration (≥9 h) were excluded in this analysis. Model 1 was adjusted for age, and Model 2 included age and was further adjusted for poverty income ratio, BMI, household size, race/ethnicity, education level, marital status, work schedule, poor mental health, general health condition, smoking status, alcohol consumption, and menopause status (only for women). All values were weighted and design corrections were applied to the analysis as directed by the National Center for Health Statistics (CDC, 2013).

SUPPLEMENTAL TABLE 3- 4 Predicted and average difference in sleep latency across food security status among low-income adults[1]

Sex Food security status	Model 1 Predicted sleep latency, *min*	Model 1 β ± SE, *min*	Model 1 *P*	Model 2 Predicted sleep latency, *min*	Model 2 β ± SE, *min*	Model 2 *P*
Men (*n* =1,422)						
Full (*n* = 845)	20	Reference	-	21	Reference	-
Marginal (*n* =230)	24	3±1.5	0.05	25	4±1.5	0.02
Low (*n* =222)	26	5±2.1	0.02	25	4±2.0	0.05
Very low (*n* =125)	28	7±2.7	<0.01	26	4±2.2	0.05
Women (*n* =1,387)						
Full (*n* = 787)	24	Reference	-	25	Reference	-
Marginal (*n* =262)	25	1±1.5	0.68	25	0±1.8	0.95
Low (*n* =230)	27	3±1.4	0.05	27	2±1.4	0.20
Very low (*n* =108)	33	8±2.6	<0.01	29	4±2.7	0.11

[1] NHANES 2005-2008 were used in the analysis. Predicted sleep latency and β coefficients in minutes were from linear regression models adjusted for different control variables in the two models. Model 1 was adjusted for age, and Model 2 included age and was further adjusted for poverty income ratio, BMI, household size, race/ethnicity, education level, marital status, work schedule, poor mental health, general health condition, smoking status, alcohol consumption, and menopause status (only for women). All values were weighted and design corrections were applied to the analysis as directed by the National Center for Health Statistics (CDC, 2013).

SUPPLEMENTAL TABLE.3- 5 Association between food security status and sleep complaints among low-income adults [1]

Food security status	Adjusted OR (95% CI)	
	Model 1	Model 2
Men and women (*n* =4,567)		
Full (*n* = 2,495)	Reference	Reference
Marginal (*n* = 801)	1.26 (1.09-1.62)	1.24(1.01-1.59)
Low (*n* = 765)	1.53(1.13-2.07)	1.50(1.12-1.94)
Very low (*n* = 506)	2.08(1.55-2.80)	1.76(1.13-2.76)

[1] NHANES 2005-2010 were used in the analysis. Adjusted OR were from logistic regression models adjusted for different control variables in the three models. Model 1 was adjusted for age, and Model 2 included age and was further adjusted for poverty income ratio, BMI, household size, race/ethnicity, education level, marital status, work schedule, poor mental health, general health condition, smoking status, alcohol consumption, and menopause status (only for women). All values were weighted and design corrections were applied to the analysis as directed by the National Center for Health Statistics (CDC, 2013).
OR: Odds Ratio

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Chapter 4 Recent Tobacco Exposure's Modification Effect of the Associations between Food Insecurity and Asthma among Children

Abstract

Background. Food insecurity has been linked to several childhood health conditions, including asthma.

Objective. The purpose of this study is to examine whether the association between food insecurity and asthma is moderated by recent tobacco exposure among children (3-17y).

Methods. Our population-based sample included 15,417 participants in the National Health and Nutrition Examination Survey 1999-2010. Food security status was assessed by the USDA 18-item Food Security Survey Module. Asthma was self-reported by children ≥12y or reported by proxy respondents for those children <12y. Children's recent tobacco exposure was measured by serum cotinine levels of ≥0.05 ng/ml. Logistic regression models were used to control for possible confounders in our analyses.

Results. Among children without recent tobacco exposure, those who were living in food insecure (Odds Ratio 1.42; 95% CI, 1.05-1.93) households were more likely to report asthma compared to those in fully food secure households when controlling for age, gender, race/ethnicity, family income, and numbers of rooms in the family. Among children with recent tobacco exposure, an association between food insecurity and asthma was not observed.

Conclusions. Rates of asthma are high in food insecure households regardless of cotinine levels among children. Recent tobacco exposure may not increase the risk of children living in food insecure household to have asthma.

Introduction

The latest CPS-FSS showed that 14.3%, which was 17.5 million households, were food insecure at some time during 2013 (USDA, 2014). Those households, at times, had difficulty providing enough food for one or more household members due to a lack of resources. Among households with children, 19.5% experienced food insecurity at some time during the year (USDA, 2014). Because children are mostly protected by adults from limited food resources, about one in ten households with children had both children and adults experienced food insecure.

Food insecure households have limited available resources to afford food, such that they consume less expensive foods than food secure households (Drewnowski and Darmon, 2005; Monsivais and Drewnowski, 2007). Among both children and adults, food insecurity has been reported to be associated with inadequate intake of several important nutrients, cognitive developmental deficits, behavioral and psychosocial dysfunction, and poor health (Rose, 1999; Casey et al., 2004). Although children who live in households with adults experiencing food insecurity may be protected by adults and thus may not experience food insecurity directly, the children have nevertheless been found to have a higher risk of a range of adverse health outcomes, delayed neuropsychological development, worse scores on standardized tests of academic achievement, and even poorer quality of life, compared with those live in food secure households (Cook et al., 2004; Weinreb et al., 2002; Alaimo et al., 2001; Cook et al., 2006; Skalicky et al., 2006; Alaimo et al., 2002; Whitaker et al., 2006; Casey et al., 2005). Several studies have found that food insecurity is linked to children's asthma (Kirkpatrick et al., 2010; McIntyre et al., 2000; Wehler et al., 1995). McIntyre et al. (2000) stated that the rate of asthma was higher among children who experienced food insecurity than those who were food secure.

Kirkpatrick et al. (2010) observed that youth who experienced repeated episodes of food insecurity were more likely to have asthma than those who were food secure.

Both genetic and environmental influences could determine the tendency of developing asthma (Thomsen et al., 2010). Among environmental influences, tobacco smoke exposure has been recognized as a trigger for asthma attacks among children (Quinto et al., 2013). Children with asthma whose parents are smokers have more frequent exacerbations and more severe symptoms than those whose parents are nonsmokers. Each year, tobacco use costs the U.S. $300 billion in medical expenses and $156 billion in lost productivity, including $5.6 billion due to secondhand smoke exposure (Xu et al., 2014). Because most smokers in the U.S. are poor or near poor and families with at least one smoker spend 2%-20% of their income on tobacco, smoking can largely affect family financial resources (Efroymson et al., 2001; Stellman and Resnicow, 1997; Haustein, 2006). Cutler-Triggs et al. (2008) observed that food insecurity was more prevalent and more severe in households with smokers. Armour et al. (2001) also confirmed that cigarette consumption is related to increased food insecurity and smoking was more prevalent among food insecure families than food secure families. Although it appears that food insecurity, tobacco exposure, and asthma are related among children, there is no study, to our knowledge, that have examined whether the association between household food security status and children’s asthma is modified by their exposure to tobacco smoke.

Methods

Study design and participants

This study used data from the National Health and Nutritional Examination Surveys (NHANES), which are a series of cross-sectional nationally representative health and nutrition surveys of the civilian noninstitutionalized U.S. population. The NHANES, conducted by the National Center for Health Statistics, are complex multistage probability samples. Details about the sampling and survey design information are published elsewhere (CDC, 2014). NHANES data files from six rounds were combined to yield an analytical dataset from 1999-2010.

Our study included 15,417 children aged 3-17 y from NHANES 1999-2010 who had complete information on household food security status, serum cotinine level, and self/proxy-reported asthma condition. Children who did not have family poverty income ratio (PIR) (n=868) and housing (n=16) information were excluded from our analyses. Our final analytical sample included 6,345 children with no recent tobacco exposure and 8,188 children with recent tobacco exposure.

Informed consent was obtained from all participants and the NCHS Research Ethics Review Board approved the protocol (CDC, 2012). The protocol for this study was approved by the Institutional Review Board, Office of Human Subjects Research, Auburn University.

Food Insecurity

Household food security status was measured by the 18-item Food Security Survey Module (FSSM). FSSM is a reliable and well-validated measurement tool to assess food insecurity circumstances at the household level during the past 12 month (USDA, 2000). Households are considered fully food secure when 0 items were answered affirmatively. Households are considered to have marginal food security when 1-2 items are answered affirmatively. Food insecurity households are those where 3-18 items are answered affirmatively (USDA, 2000).

Recent tobacco exposure Measurement

Children's serum cotinine levels were used to determine recent tobacco exposure, including both active and passive exposure. During the participants' physical examination at the mobile examination centers (MECs), children's blood samples were collected. Serum cotinine levels were used to indicate recent tobacco exposure, because cotinine is a major metabolite of nicotine and the half-life of cotinine is about 18 h, whereas the half-life of nicotine is about 2 h (Patrick 1994). Serum cotinine is considered the "fluid of choice" because of its longer half-life and specificity for tobacco exposure (Patrick et al., 1994). Thus, we used children's serum cotinine level to measure whether they were exposed to tobacco smoke. The blood collection techniques and the cotinine assay method information are described elsewhere (CDC, 2015a). Serum cotinine levels ≥ 0.05 ng/mL indicated recent tobacco exposure and levels < 0.05 ng/mL were deemed as no exposure (Pirkle et al., 1996; CDC, 2008).

Asthma

During the household interview, children ≥12 y were asked if they had ever been told by a doctor or other health professional that they had asthma. If the children were less than 12 y, proxy respondents would answer questions regarding children's health status.

Socioeconomic characteristics

Socioeconomic information was collected during the household interview. We categorized children's age at the time of their screening interview as preschoolers (3-5 y), middle childhood (6-11 y) and teenagers (12-17 y) (CDC, 2015b). Race/Ethnicity were classified as non-Hispanic white, non-Hispanic black, Mexican-American, and other races, including other Hispanic and multiracial. Poverty income ratios (PIR), which were ratios of family income to Department of Health and Human Services' poverty guidelines, was grouped as ≤185% and >185% (USDA, 2014). Numbers of rooms in the home were dichotomized as ≤ 6 and > 6.

Data Analysis

Analyses were conducted using SAS 9.1 (SAS Institute Inc, Cary, NC). Sampling weights and sample design variables from the six survey rounds were applied to account for the stratification and clustering of observations in NHANES (CDC, 2013).

The second order interaction terms of food security status and smoking status were statistically significant ($P < .05$) for the likelihood of asthma. Based on these findings, we stratified our analysis by exposure to tobacco smoke. We used χ-square tests of independence to test the associations between socioeconomic characteristics and food insecurity among children with and without recent tobacco exposure. Logistic regression models were used to examine the association between food insecurity and asthma. The reference groups in the logistic modeling were full food security, female, age 12-17y, non-Hispanic white, PIR>185%, and having >6 rooms at home.

Results

Characteristics, including children's sex, age, race/ethnicity, PIR, and numbers of household rooms, are shown in Table 4-1 by children's recent tobacco exposure condition across food security status. Differences across food security status in both recent tobacco exposure conditions were found for race/ethnicity, PIR and numbers of rooms in family. Figure 2 represents the prevalence of asthma for fully food secure, marginally food secure, and food insecure children stratified by their recent tobacco exposure. Among those who did not have recent tobacco exposure, 18% children living in food insecure household had asthma, whereas about 15% children living in fully and marginally food secure household had asthma. Among those who had recent tobacco exposure, the prevalence of asthmatic children were 19% in food insecure household, 20% in marginally food secure household and 17% in food secure household. Reported asthma was independent of food security status in both recent tobacco exposure condition in the bivariate analysis.

The interaction terms (recent tobacco exposure and food insecurity) used to investigate moderation effect of recent tobacco exposure in the association between food insecurity and asthma were statistically significant in logistics regression models adjusted for control variables ($P < 0.05$). Thus, analyses were stratified by recent tobacco exposure. Among children with no recent tobacco exposure, those who were living in food insecure household were more likely to have reported asthma than their food secure counterparts (Adjusted OR 1.42; 95% CI 1.05-1.93), whereas marginal food security was not related to asthma (Table 4-2). Among children with recent tobacco exposure, food security status was not associated with asthma. In addition, among children with recent tobacco exposure, Mexican American were less likely to have asthma than their Non-Hispanic White counterparts (Adjusted OR 0.73; 95% CI 0.57-0.92), whereas the association did not exist among children with no recent tobacco exposure.

Discussion

To our knowledge, our study is the first to demonstrate recent tobacco exposure's modification effect of the association between food insecurity and asthma among children. By using serum cotinine levels to indicate recent tobacco exposure condition, we observed two different results on recent tobacco exposure's modification effect as we hypothesized. However, surprisingly, we did not obtain the results as we expected in which recent tobacco exposure would possibly increase the risk of having asthma for those children living in food insecure households. Among children with no recent tobacco exposure, those who lived in food insecure households were at higher risk of reported asthma than those who lived in fully food secure households, whereas, there is no difference in the risk of reported asthma for children with recent tobacco exposure living in households with different food security status.

Comparisons between the results of this study and previous studies are difficult because, to our knowledge, no other research has been published on recent tobacco exposure's modification effect of the relation between household food insecurity and asthma among children. Food insecurity happens in households with limited resources, which forces members in such households to make choices among subsistence needs and other competing needs, such as smoking (Anderson et al., 1990). It has been suggested that smoking could contribute to nutritional deprivation among households that were already disproportionally influenced by poverty, which is strongly related to food insecurity and poor health outcomes (Iglesia-Rios et al., 2015). Previous studies have noted that the prevalence of asthma is higher among children living in food insecure households compared to food secure households (Kirkpatrick et al., 2010) and recent tobacco exposure can trigger an asthma attack among children (Quinto et al., 2013). However, tobacco exposure may be an adjuvant factor in determining asthma among genetically predisposed children, but not among nonpredisposed children (Agabiti et al., 1999). Thus, for children with recent tobacco exposure, the link between food insecurity and asthma could be attenuate as recent tobacco exposure may have already categorize children into “asthma” and “non-asthma” groups based on their genetic predisposing condition. For children without recent tobacco exposure, our results are consistent with previous studies on relation between food insecurity and asthma. Two longitudinal studies from Canada found the rates of asthma were higher among food insecure children than their food secure counterparts (Kirkpatrick et al., 2010; McIntyre et al., 2000).

The mechanism that underlies the relationship between food insecurity and asthma among children without recent tobacco exposure has obviously not been established. Previous study has found that children who experienced stressful life events are more likely to have asthma than their counterparts (Turyk et al., 2008). Household food insecurity is one of the stressful life events that could disturb children’s cortisol reactivity through stimulation of the hypothalamic-pituitary-adrenal system and its impact on immature corticolimbic structures and pathways. (Ouellet-Morin et al., 2008). Also, inflammation is an integral part of the stress response and the secretion of proinflammatory cytokines could increase through the stimulation of the sympathetic-adrenome-dullary system by catecholamines (Kelsay et al., 2013). The variations in the cortisol level and mismatch between these two systems have been linked to asthma (Buske-

Kirschbaum et al., 2003). Another possible mechanism of the association between household food insecurity and children's asthma is through the mother. Household food insecurity has been related to mothers' psychological distress, depression, anxiety and maternal stress, which could have negative emotional and psychological effects on mothers' children that may exert a poor general health or diseases among children (Murphy et al., 1998; Belsky et al., 2010; Cook et al., 2004). Also, mothers' impaired emotional condition could weaken the mother-child bond, and thus impact the level of children's care and increase the risk of disease (Ribeiro-Silva et al., 2014; Weinreb et al., 2002; Alaimo et al., 2001).

There were some limitations to our outcome measures. Firstly, our study used serum cotinine level to measure recent tobacco exposure, which can accurately determine children's recent contact to tobacco, including both active and passive exposure, through different exposure occasions, such as home, cars, and restaurants. Whereas other measurements, such as self-report, might not capture all children that had recent tobacco exposure. However, the 18 h half-life of cotinine limits the detection of a longer period of children's recent tobacco exposure, although the half-life of cotinine is already longer than the 2 h half-life of nicotine (Patrick 1994). Secondly, whether children had ever had asthma was measured according to participants' self-report or proxy-report, which was potentially subject to recall bias. Lastly, our study is limited by the cross-sectional nature of NHANES, which does not allow us to determine a causal relationship. Reverse causation is possible in that medical expense of children's asthma leads to worsened financial constraint and thus leads to food insecurity.

In conclusion, results from this study suggest that recent tobacco exposure may not increase the risk of children living in food insecure household to have asthma. Participation in food and nutrition assistance programs is necessary to alleviate food insecurity, which may have the potential to decease children's risk of asthma. Further understanding of the association between food insecurity and asthma modified by recent tobacco exposure is needed and may inform clinical care and interventions for children at risk for asthma.

Table 4-1. Characteristics of children (3-17y) across food security status by recent tobacco exposure condition: NHANES 2003-2010

	No recent tobacco exposure (n = 6,345)				Recent tobacco exposure (n = 8,188)			
Characteristics	Full food security (n=4391)	Marginal food security (n=645)	Food insecurity (n=1309)	P	Food security (n=4676)	Marginal food security (n=1045)	Food insecurity (n=2467)	P
				Percent				
Sex				.49				.73
Female	48.7	48.4	48.2		48.1	49.0	47.2	
Male	51.3	51.6	51.8		51.8	50.9	52.8	
Age (y)				.91				.30
12-17	45.7	47.3	44.6		45.6	41.2	43.9	
6-11	40.6	40.3	41.7		38.5	39.8	40.0	
3-5	13.7	12.4	13.7		15.9	19.0	16.1	
Race/ Ethnicity				<.001				<.001
Non-Hispanic White	66.4	32.6	19.5		68.1	45.6	47.5	
Non-Hispanic Black	7.1	14.5	13.4		15.9	28.9	23.3	
Mexican American	12.6	37.6	51.12		6.3	12.0	13.9	
Other races[a]	14.0	15.3	15.9		9.7	13.5	15.3	
PIR [b] (%)				<.001				<.001
>185	79.5	32.7	20.1		57.0	29.0	13.8	
≤185	20.5	67.3	79.9		43.0	71.0	86.2	
No. of rooms				<.001				<.001
>6	65.0	29.5	18.0		46.9	24.2	25.1	
≤6	35.0	70.5	82.0		53.1	75.8	74.9	

NHANES 1999-2010 were used in the analysis. Sampling weights and sample design variables from the six survey rounds were applied to account for the stratification and clustering of observations in NHANES (CDC, 2013). Column percentages do not always add up to 100% because of rounding.

[a] Other races includes other Hispanic and multi-racial.

[b] Poverty income ratio was calculated by dividing family income by the annual poverty threshold provided by U.S. Census Bureau.

Table 4-2. Adjusted odds ratios (95% confidence intervals) for asthma by recent tobacco exposure condition

	No recent tobacco exposure (n = 6,345)	Recent tobacco exposure (n = 8,188)
Food security status		
Full food security	Reference	Reference
Marginal food security	1.06 (0.76 1.48)	1.25 (0.98 1.61)
Food insecurity	1.42 (1.05 1.93)	1.18 (0.97 1.43)
Sex		
Female	Reference	Reference
Male	1.33 (1.09 1.62)	1.31 (1.12 1.54)
Age (y)		
12-17	Reference	Reference
6-11	0.78 (0.64 0.94)	0.85 (0.71 1.03)
3-5	0.56 (0.40 0.78)	0.75 (0.60 0.93)
Race/ Ethnicity		
Non-Hispanic White	Reference	Reference
Non-Hispanic Black	1.56 (1.19 2.04)	1.28(1.03 1.58)
Mexican American	0.81(0.61 1.07)	0.73 (0.57 0.92)
Other races[a]	1.30 (0.94 1.79)	1.18(0.93 1.51)
PIR [b] (%)		
>185	Reference	Reference
≤185	0.89 (0.67 1.18)	0.91 (0.73 1.14)
No. of rooms		
>6	Reference	Reference
≤6	0.94 (0.76 1.18)	1.15 (0.94 1.39)

NHANES 1999-2010 were used in the analysis. Sampling weights and sample design variables from the six survey rounds were applied to account for the stratification and clustering of observations in NHANES (CDC, 2013). Adjusted ORs were from logistic regression models adjusted for age, sex, race/ethnicity, PIR, and numbers of rooms.

[a] Other races includes other Hispanic and multi-racial.

[b] Poverty income ratio was calculated by dividing family income by the annual poverty threshold provided by U.S. Census Bureau.

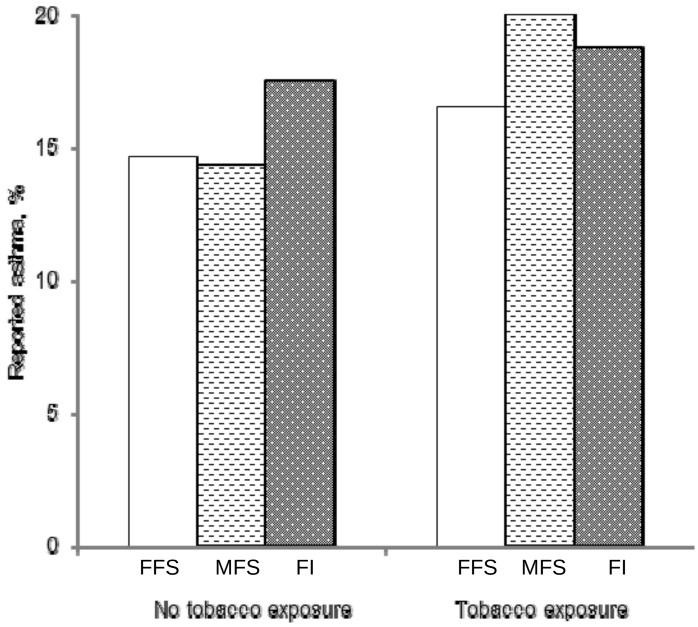

Figure 2. Prevalence of asthma for fully food secure, marginally food secure and food insecure children stratified by their recent tobacco exposure. NHANES 1999-2010 were used in the analysis. Sampling weights and sample design variables from the six survey rounds were applied to account for the stratification and clustering of observations in NHANES (CDC, 2013).

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Chapter 5 Socioeconomic Characteristics and Misclassification of Tobacco Exposure among Children

Abstract

Background. Previous studies have shown underestimates of smoking prevalence by self-reporting.

Objective. To estimate the misclassification of young children's tobacco exposure and its association with socioeconomic characteristics, including children's sex, age, race/ethnicity, family income, numbers of household rooms, and household food security status.

Methods. Our population-based sample included 6,328 participants (3-10y) in the National Health and Nutrition Examination Survey 1999-2010. Self-reported tobacco exposure by household reference participants were compared to children's serum cotinine levels. Serum cotinine levels of $\geqslant$0.05 ng/ml were indicative of tobacco exposure. Logistic regression models were used to estimate the association between socioeconomic characteristics and misclassification of tobacco exposure.

Results. Children who were younger (Adjusted OR 1.38, 95% CI 1.16-1.64), Non-Hispanic Black (Adjusted OR 1.38, 95% CI 1.16-1.64), living in low PIR families (Adjusted OR 1.38, 95% CI 1.10-1.71), and living in smaller housing (Adjusted OR 1.50, 95% CI 1.21-1.87) were more likely to be misclassified for tobacco exposure than their counterparts. In the crude model, children living in food insecure household were more likely to be misclassified of tobacco

exposure than those living in food secure household (OR 1.27, 95% CI 1.04-1.55), but the association was attenuated after other characteristics taken into account in the full model. Sex was not found to be associated with misclassification of tobacco exposure.

Conclusions. Proxy-reports of tobacco exposure among children, especially preschooler, non-Hispanic Black, and those living in shortage of resources, may be biased

Introduction

In the U.S., cigarette smoking is the leading cause of death and preventable disease (CDC, 2014). In 2013, about 17.8% (42.1 million) American adults are current cigarettes smokers (CDC, 2014). About three in five (22 million) children aged 3-11y in the U.S. are secondhand/passive smokers, who are exposed to the smoke from the burning end of a cigarette and from the breath-out by active smokers (USDHHS, 2006). Tobacco smoke has at least 7,000 chemicals of which 70 are known toxic or carcinogenic chemicals, including formaldehyde, benzene, vinyl chloride, arsenic, ammonia, and hydrogen cyanide (USDHHS, 2014a; USDHHS, 2014b; USDHHS, 2010; USDHHS, 2006). Children who have passive smoke exposure are inhaling as many of these toxic and carcinogenic substances as those who are active smokers. Because of the development of children's body, infants and young children are most vulnerable to these poisons. Tobacco exposure can cause serious health problems in children (USDHHS, 2006; USDHHS, 2014b). Tobacco exposure is harmful to children's respiratory system and linked to a higher risk of middle ear infections, bronchitis, pneumonia, coughing, wheezing, poor lung function, and asthma development (Quinto et al., 2013).

As the negative effects of passive tobacco exposure on children's health have been increasingly publicized, smoking is treated as one of the most undesirable health and social behaviors, especially among parents (Gorber et al., 2009). Thus, it is possible that people may not be willing to admit this undesirable behavior, so that smoking may be prone to be underreported. Some studies have noted that using self-reported estimates may underestimate actual smoking prevalence (Lewis et al., 2003; Tyrpien et al., 2001). Surveys often measure the prevalence of tobacco smoking by collecting self-reported information, which typically rely on participants' words at the interview (Gorber et al., 2009). The degree of misclassified smoking status depends on the population examined. For example, Klebanoff et al. (2001) stated that the population of pregnant women, who are perceived not to have prenatal smoking, may have a high rate of misclassification of their smoking status. However, few studies have examined other subpopulation on the misclassification of young-age children's tobacco exposure and its association with socioeconomic characteristics, including children's sex, age, race/ethnicity, family income, numbers of household rooms, and household food security status.

Methods

Sample

The National Health and Nutritional Examination Surveys (NHANES) are a series of cross-sectional surveys designed to be nationally representative and to assess the health and nutritional status of the civilian noninstitutionalized U.S. population. The NHANES, conducted by the National Center for Health Statistics, were collected with a stratified, multistage probability cluster design. Details about the recruitment, sampling and survey design information are described elsewhere (CDC, 2013b). During the household interview, questions about demographic characteristics and health-related behaviors were collected. Physical exams and various biological specimens were collected when participants reported to the Mobile Examination Center (MEC). Laboratory tests include the collection of various biological specimens, such as blood samples for participants 1 year and older and urine samples for those 6 years and older.

NHANES' data files were released in 2-year rounds and we used the six rounds of NHANES 1999-2010. There were 6,704 children aged 3-10 y who had complete information on household food security status and serum cotinine level. We excluded those who did not have income (n= 369) and housing information (n=7). Our final analytical sample included 6,328 children.

The NCHS Research Ethics Review Board approved the protocol and informed consent was obtained from all participants (CDC, 2012). The protocol for this secondary study was approved by the Institutional Review Board, Office of Human Subjects Research, Auburn University.

Tobacco exposure by proxy-report

During the household interview, NHANES participants were asked whether anyone who lives in the household smoked cigarettes, cigars, or pipes anywhere inside the home. An eligible proxy for the family questionnaire must be at least 18 y and a family member (CDC, 2013a). S/he answered questions about the smoking status of all members of the household. If there was no one 18 years or older, the head of the family or any person in the family who has ever been married would be interviewed.

Tobacco exposure by serum cotinine level

Children's blood samples were collected at the MECs and several tests including serum cotinine measurements were performed. Cotinine is a major metabolite of nicotine and has a longer half-life than nicotine (Patrick et al., 1994). Accordingly, cotinine is preferred as a biomarker for tobacco exposure whether that exposure is a result of the participant actively smoking and/or being exposed to "second-hand smoke." Although cotinine can be measured in other body fluids, such as urine or saliva, serum cotinine has been chosen to measure cotinine level for studies requiring a quantitative assessment (Patrick et al., 1994). Thus, for this study serum cotinine was used to indicate children's tobacco exposure. Blood collection techniques and the cotinine assay method information are described elsewhere (CDC, 2015a). Those children who had serum cotinine measurements ≥ 0.05 ng/ml were defined as recent tobacco exposure (CDC, 2008).

Misclassification of tobacco exposure

Misclassification of tobacco exposure was determined by comparing proxy-reports to clinical evidence. Serum cotinine levels were used to determine whether proxy-reported tobacco exposure at the time of enrollment accurately reflected children's tobacco exposure.

Socioeconomic Characteristics

During the household interview, children's sex and age in years at the time of the screening interview were reported. Children's age was categorized to preschoolers (3-5 y) and middle childhoods (6-10 y) (CDC, 2015b). Participants also responded to questions on race and Hispanic origin, family income, numbers of household rooms, and food security status. Race/Ethnicity were classified as non-Hispanic white, non-Hispanic black, Mexican-American, and other races, including other Hispanic and multiracial. Poverty income ratios (PIR) (ratios of family income to Department of Health and Human Services' poverty guidelines) were calculated. Values for PIR ranged from 0 to 500% with 500% being the code for PIR ≥ 500% because of disclosure concerns. We grouped PIR as ≤185% and >185%, because it is the upper boundary for several Food and Nutrition Service programs and often used in analyses (USDA, 2014). Numbers of rooms in the home were dichotomized as ≤ 6 and > 6. Food security status was measured by the 18-item Food Security Survey Module, which measures the presence of food insecurity at the household level during the past 12 mo (USDA, 2000). Food insecurity happens “whenever the availability of nutritionally adequate and safe foods or the ability to acquire acceptable foods in socially acceptable ways is limited or uncertain. (LSRO, 1990)” Households were considered full food security when 0 items were answered affirmatively and marginal food security when 1-2 items were answered affirmatively. Food insecurity referred to those households when 3-18 items were answered affirmatively (USDA, 2000).

Statistical Analysis

Sampling weights and sample design variables from the six survey rounds were accounted for in the analyses. Data were analyzed using Statistical Analysis Systems statistical software package version 9.2 (SAS Institute, Cary, NC, USA). All values were considered significant at $P \leq 0.05$.

Logistic regression models were used to examine the relationship between misclassification of tobacco exposure and participants’ socioeconomic characteristics. Several model specifications, including testing each characteristic alone and a full model were used in our regression analyses. In all analyses, sex, age, race/ethnicity, PIR, numbers of rooms at home, and food security status were used as indicator variables.

Results

Overall, 20% of children’s proxy reported that the children might have been exposed to tobacco at home (Figure 3), whereas 57% of children had detectable serum cotinine, indicating recent exposure to tobacco. Table 5-1 summarized the characteristics, including children’s sex, age, race/ethnicity, family PIR, numbers of household rooms, and food security status, by children's tobacco exposure condition and misclassification status of tobacco exposure. When tobacco exposure condition was measured by proxy-report, differences were found between no tobacco exposure and tobacco exposure for race/ethnicity, PIR, numbers of rooms in family, and food security status. When tobacco exposure condition was measured by clinic evidence of serum cotinine, differences were found between no tobacco exposure and tobacco exposure for age, race/ethnicity, PIR, numbers of rooms in family, and food security status. Regarding the misclassification status of tobacco exposure, characteristics, including age, race/ethnicity, PIR, numbers of rooms in family, and food security status were not independent of misclassification status.

In Table 5-2, we used both crude logistic regression models, which had one single characteristics variable in each model alone, and full models, which adjusted for all of the characteristics variables together in one full model. According to the crude model, preschoolers were 28% more likely to be misclassified for tobacco exposure than those in middle childhood (OR 1.28, 95% CI 1.09-1.50) (Table 5-2). Similar results were observed after adjusting for other characteristics (Adjusted OR 1.24, 95% CI 1.04-1.48). Non-Hispanic Black children were more than 30% more likely to be misclassified for tobacco exposure than Non-Hispanic White children in both crude (OR 1.68, 95% CI 1.44-1.97) and full (Adjusted OR 1.38, 95% CI 1.16-1.64) models. Mexican American children were found less likely to be misclassified than Non-Hispanic White children in both models (OR 0.81, 95% CI 0.68-0.97; Adjusted OR 0.54, 95% CI 0.44-0.68). We observed that children living in low PIR families had higher odds of being misclassified of tobacco exposure than those who were living in high PIR families (OR 1.54, 95% CI 1.29-1.83;

Adjusted OR 1.38, 95% CI 1.10-1.71). Children who were living in smaller housing were more likely to be misclassified of tobacco exposure than those who were living in bigger housing (OR 1.61, 95% CI 1.31-1.96; Adjusted OR 1.50, 95% CI 1.21-1.87). In the crude model, children living in food insecure household were more likely to be misclassified of tobacco exposure than those living in food secure household (OR 1.27, 95% CI 1.04-1.55), but the association was attenuated after other characteristics taken into account in the full model. Sex was not found to be associated with misclassification of tobacco exposure.

Discussion

To our knowledge, our study is the first to demonstrate associations between proxy-reported misclassification of tobacco exposure and participants' demographic and socioeconomic characteristics, including age, race/ethnicity, family income, housing, and food insecurity, among children. Our results indicate that smoke status may be underreported by parents, especially for those who have younger, non-Hispanic Black children or children who are living in low income families, smaller house, or food insecure families. Our results suggest that parental reports should not be trusted when evaluating children's tobacco exposure and it would be necessary to measure tobacco exposure by biomarker levels.

Previous studies have reported underestimation of children's tobacco exposure by parent-report information. Boyaci et al. (2006) found that the percentage of tobacco exposure at home measured by cotinine level was two times more than the percentage of parents' declaration. Some possible reasons for misclassification were considered. Firstly, participants might wish to report behaviors consistent with a healthy life-style (Wagenknecht et al., 1992). Chirstensen et al. (2004) have proposed that being aware of the health risks for children from tobacco exposure could be a bias for assessing objectively children's tobacco exposure. Several studies have supported this proposal that children's tobacco exposure might be underestimated by parent-report and it should not be completely trusted (Puig et al., 2008). Secondly, participants may have misunderstood the household smoking question provided by NHANES. Proxies were asked whether anyone who lives in the household smoked anywhere inside the home. Although it is mostly likely that the proxies were the participated children's parents, the proxies may not have known the family members' smoking status because of lacking information on the relationship of proxies and children. Also, household members who were "light" smoker might be neglected by proxies. Thirdly, it is possible that children may contact other tobacco exposure occasions, such as exposure in transportations, public parks, and restaurants. Third-hand smoke is "particles and gases given off by cigarettes that cling to walls, clothes and even hair and skin." (USDHHS, 2006) Some studies have shown that "babies of parents who smoke only outside had cotinine levels seven times higher than in the infants of non-smokers" (USDHHS, 2006). However, Mannino et al. (2001) reported that the reported number of cigarettes smoked in the home is the most important predictor of cotinine levels in children exposed to smoke.

A nationally representative study of U.S. children has found that among children with no self-reported smoke exposure, significant predictors of increased cotinine levels include young age, black race, low number of rooms in the home, and low family poverty index (Mannino et al., 2001). Among adults, several studies reported factors that have been linked to the accuracy of self-report of smoking include age, race/ethnicity, and education level (Caraballo et al., 2001; Klesges 1992; Wagenknecht et al., 1992). In this study, we found that children's age, race/ethnicity, family income, numbers of rooms at home, and food insecurity could predict the discrepancy in parent-reported and biomarker-tested tobacco exposure. Firstly, for those who have younger children at home, parents are more likely to "hide" their smoking status than those parents who have relatively older ones. It is possible that parents with younger children may not be willing to admit they are smokers, because younger children are especially vulnerable to the toxic and carcinogenic substances from inhaling tobacco smoke (USDHHS, 2006). Secondly, regarding race/ethnicity, our results indicated that non-Hispanic Black families were more likely to have misclassification of tobacco exposure. Wagenknecht et al. (1992) stated that Black subjects had two times higher misclassification rate of smoking than White subjects. We also found that Mexican American were less likely to underreport children's tobacco exposure than non-Hispanic White. Thirdly, the numbers of rooms at home predicted the discrepancy in tobacco exposure measurements. It is possible that whether the parents smoke at home might not affect children's blood cotinine level among children living in larger house, because these children might stay far away from their smoking parents. Fourthly, our results on family income as a predictor of misclassification of tobacco exposure were consistent with other studies on self-report of smoking (Mannino et al., 2001). Because families with a low income are highly related to low educated members in the family, those parents might misunderstand the smoking questions (Wagenknecht et al., 1992). Thus, the rate of underreported tobacco exposure might be higher among children living in low income families than their high income counterparts. Unfortunately, because NHANES did not collect the education information of the proxy, who answered the smoking question, we could not estimate the association between education and misclassification of children's tobacco exposure. Lastly, our results indicated that children living in food insecure families were more likely to be misclassified for tobacco exposure. However, adjusting other characteristics attenuated the link between food insecurity and the misclassification. Household food insecurity has been related to mothers' psychological distress, depression, anxiety and maternal stress (Weinreb et al., 2002). It is possible that food insecure parents might answer the smoking question with stress and thus might not provide an accurate answer of their smoking status.

In conclusion, proxy-reports of tobacco exposure among children, especially preschooler, non-Hispanic Black, and those living in shortage of resources, may be biased. Identifying characteristics that contribute to misclassification of children's tobacco exposure could provide more accurate estimates of secondhand smoking prevalence and have important implications, because secondhand smoking prevalence could be used to monitor smoking trends, estimate tobacco-related risks, and justify spending for research and tobacco control programming (Gorber et al., 2009). Further research is needed to better investigate the underline reason of the association between the socioeconomic characteristics and the misclassification of tobacco exposure among children.

Table 5-1 Characteristics of children (3-10y) by misclassification of tobacco exposure: NHANES 1999-2010

Characteristics	Tobacco exposure condition						Misclassification status		
	Measured by proxy-report			Measured by serum cotinine			Agreement (n=3908)	Non-agreement (n=2420)	P-value
	No tobacco exposure (n=5115)	tobacco exposure (n=1213)	P-value	No tobacco exposure (n=2735)	tobacco exposure (n=3593)	P-value			
	Percent								
Sex			.09			.09			.99
Female	46.5	50.2		45.6	48.5		47.2	47.2	
Male	53.5	49.8		54.4	51.5		52.8	52.8	
Age (y)			.25			.004			.030
6-10	68.0	70.3		70.8	66.7		70.5	65.1	
3-5	32.0	29.7		29.2	33.3		29.5	34.9	
Race/ Ethnicity			<.001			<.001			<.001
Non-Hispanic White	55.5	66.9		55.4	59.7		59.0	55.8	
Non-Hispanic Black	13.1	18.6		8.3	18.8		11.7	18.6	
Mexican American	16.8	5.0		21.0	9.5		15.8	12.1	
Other races [a]	14.4	9.5		15.3	12.1		13.5	13.4	
PIR [b] (%)			<.001			<.001			<.001
>185	56.0	29.8		66.7	38.6		54.7	44.0	
≤185	44.0	70.2		33.3	61.4		45.3	56.0	
No. of rooms			<.001			<.001			<.001
>6	45.1	32.4		53.5	34.2		46.8	35.4	
≤6	54.9	67.6		46.5	65.8		53.2	64.6	
Food security status			<.001			<.001			.030
Full food security	75.2	55.9		81.4	63.6		73.0	68.5	
Marginal food	8.5	13.2		6.9	11.4		9.0	10.2	

security						
Food insecurity	16.3	30.9	11.72	25.0	18.0	21.4

The sampling weights and sample design variables from the six survey rounds were accounted for the stratification and clustering of observations in the analyses, according to NCHS (CDC, 2013b). Column percentages do not always add up to 100% because of rounding.

[a] Other races includes other Hispanic and multi-racial.

[b] Poverty income ratio was calculated by dividing family income by the annual poverty threshold provided by U.S. Census Bureau.

Table 5-2 Crude and adjusted odds ratios (95% confidence intervals) for misclassification of children's tobacco exposure by characteristics

Socioeconomic Characteristic	Crude model: OR (95% CI)	Full model: adjusted OR (95% CI)
Sex		
Female	Reference	Reference
Male	1.00 (0.88 1.14)	1.00 (0.87 1.14)
Age (y)		
6-10	Reference	Reference
3-5	1.28 (1.09 1.50)	1.24 (1.04 1.48)
Race/ Ethnicity		
Non-Hispanic White	Reference	Reference
Non-Hispanic Black	1.68 (1.44 1.97)	1.38 (1.16 1.64)
Mexican American	0.81 (0.68 0.97)	0.62 (0.50 0.76)
Other races[a]	1.05 (0.81 1.35)	0.92 (0.72 1.18)
PIR[b] (%)		
>185	Reference	Reference
≤185	1.54 (1.29 1.83)	1.38 (1.10 1.71)
No. of rooms		
>6	Reference	Reference
≤6	1.61 (1.31 1.96)	1.50 (1.21 1.87)
Food security status		
Full food security	Reference	Reference
Marginal food security	1.20 (0.94 1.54)	0.97 (0.75 1.24)
Food insecurity	1.27 (1.04 1.55)	1.02 (0.79 1.32)

The sampling weights and sample design variables from the six survey rounds were accounted for the stratification and clustering of observations in the analyses, according to NCHS (CDC, 2013b). ORs were from logistic regression crude models with each characteristics individually. Adjusted ORs were from logistic regression full models, including all of the characteristics variables together in one model.

[a] Other races includes other Hispanic and multi-racial.

[b] Poverty income ratio was calculated by dividing family income by the annual poverty threshold provided by U.S. Census Bureau.

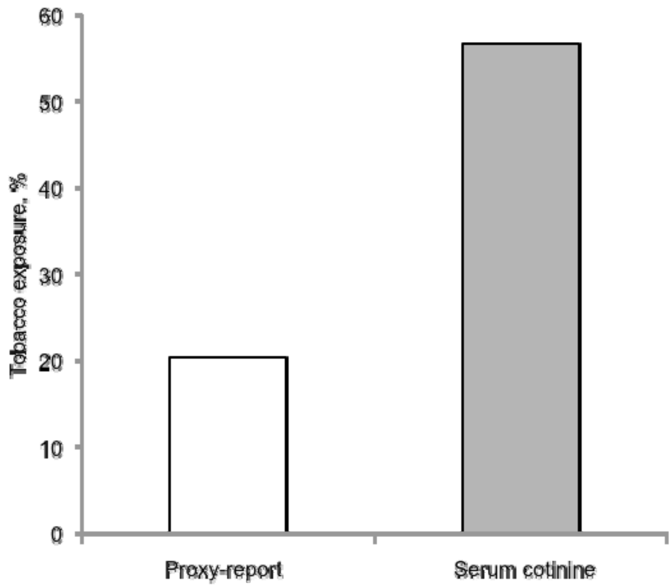

Figure 3. Prevalence of children's tobacco exposure by proxy-report and serum cotinine. NHANES 1999-2010 were used in the analysis. Sampling weights and sample design variables were applied to account for the stratification and clustering of observations in NHANES (CDC, 2013b).

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