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Food Insecurity and Physical Activity among U.S. populations

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FOOD INSECURITY AND PHYSICAL ACTIVITY AMONG U.S. POPULATIONS

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ABSTRACT

Objectives: Examine the association between food insecurity (FI) and physical activity (PA) in the U.S. population.

Methods: Accelerometry (PAM) and self-report PA (PAQ) data from NHANES 2003-2006 were used. Those aged less than six years or were older than 65 years, pregnant, with physical limitations, or with family income above 350% of the poverty line were excluded. FI was measured by the USDA Household Food Security Survey Module. Crude and adjusted odd ratios were calculated from logistic regression to identify the association between FI and adherence to the PA recommendation. Crude and adjusted coefficients were calculated from linear regression to identify the association between FI and both sedentary and activity minutes.

Results: In children, FI was not associated with adherence to PA recommendation measured via PAM or PAQ (p>0.05) but was significantly associated with sedentary minutes (adjusted coefficient=10.74, one-sided p<0.05). Food-insecure children did less moderate-to-vigorous PA than did food-secure children (adjusted coefficient = -5.31, p = 0.032). In adults, FI was significantly associated with PA (adjusted OR=0.722 for PAM and OR=0.839 for PAQ, one-sided p<0.05) but not associated with sedentary minutes (p>0.05)

Conclusions: FI children were more sedentary and FI adults were less likely to adhere to

the PA recommendation than those without FI

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LIST OF ABBREVIATIONS

FAO...Food and Agriculture Organization

FI... Food Insecurity

HFSSM ....Household Food Security Survey Module

HH.. Household

HHRP.. Household Reference Person

MEC..Mobile Examination Center

MPA...Moderate intensity Physical Activity

MVPA.. Moderate and Vigorous intensity Physical Activity

NCHS.. The National Center for Health Statistics

NH... Non-Hispanic

NHANES ....The National Health and Nutrition Examination Survey

OR .... Odds Ratio

PA ....Physical Activity

PAGA... The Physical Activity Guidelines for Americans

PAM...Accelerometry data

PAQ...Self-report Physical Activity data

PIR .... Poverty Income Ratio

USDA..The U.S. Department of Agriculture

VPA.. Vigorous intensity Physical Activity

CHAPTER 1

INTRODUCTION

Food insecurity (FI) is a public-health concern in the U.S. FI is defined by the Life Sciences Research Office (LSRO) of the Federation of American Societies for Experimental Biology as "limited or uncertain availability of nutritionally adequate and safe foods or limited or uncertain ability to acquire acceptable foods in socially acceptable ways"[1] or by Food and Agriculture Organization (FAO) as a situation "when people do not have adequate physical, social or economic access to sufficient, safe and nutritious food which meets their dietary needs and food preferences for an active and healthy life[2]. In 2012, 14.5% or 17.6 million U.S. households were food-insecure[3]. About 5.7% or seven million households had very low food security that caused at least one household member to reduce food intake at times during the year[3].

FI is associated with poor physical and mental health outcomes among both children and adults[4, 5]. Children living in food-insecure households were more likely to have cognitive development deficits, behavioral and psychosocial problems, and poorer general health[4, 6-8].Similarly, food-insecure adult were more likely to have type 2 diabetes, cardiovascular diseases, hypertension, hyperlipidemia, and inflammation[9-13].The association between FI with obesity, however, is not consistent across studies or subpopulations[14]. Eisenmann et al. (2011) reported mixed results with positive, negative, and null associations after reviewing 21 studies[15]. The review of Larson et al. (2011)

also found mixed results among children and men but positive association among women[16]. Franklin et al. (2012) reviewed 19 studies since 2005 and found a strong positive association among women but mixed results among children[17]. FI was also found to be associated with depression among mothers[18], elders[19] and HIV infected women[20].

FI may affect these health outcomes by causing changes in metabolism and behavior including selecting foods with high energy, overeating when food is available, and stress and anxiety[6, 21, 22]. FI may also cause changes in physical activity (PA) behaviors. Due to lack of healthy food, it is possible that FI people are less physiologically and psychologically energetic and therefore less likely to do PA and more likely to have poorer health. The relationship between FI and PA, however, has not been thoroughly investigated. We have found only one study on this relationship; in that study, adolescents experiencing FI were less physically active than those with food security[21]. Only one question, which asked about the frequency of spending free time doing things involving physical effort, was used to measure PA.

Investigating the association of FI with PA is important because low PA is itself a public-health concern in the U.S. and other countries facing high rates of chronic disease. While strong evidence shows numerous physical and mental health benefits of PA such as lower risks of cardiovascular diseases, diabetes, reduced depression, and obesity[23, 24], PA level among U.S. populations is low[25-27]. The Physical Activity Guidelines for Americans (PAGA)[23] recommend that adults should total at least 150 minutes/week of

moderate intensity (MPA), or 75 minutes/week of vigorous intensity physical activity

(VPA), or an equivalent combination of both (MVPA), and that children and adolescents

should do for at least 60 minutes daily. Accelerometer data, however, showed that less

than 10% of adults and adolescents[26, 27] met the PAGA. The percentage was 42% for

children 6-11years[27].

This study, therefore, aims to examine the association between FI and PA in the

U.S. population. We hypothesize that FI people are less likely to adhere to the PAGA

recommendation and more likely to be sedentary than those without FI.

In summary, this chapter identifies and describes a gap in literature which is the

lack of studies on the relationship between FI and PA. It also shows the importance of

understanding this relationship in assessing and interpreting the effectiveness of FI

interventions. Chapter 2 provides a review of recent literature relevant to FI and PA in the

U.S. Chapter 3 is a description about the data source and methodology used in the study.

Chapter 4 is the thesis written in the manuscript format which is ready to submit for

publication in theAmerican Journal of Public Health. Chapter 5 provides a conclusion

and implications of the study as well as suggests recommendations for future research.

CHAPTER 2

LITERATURE REVIEW

The purpose of this chapter is to review current literature about (i) the current status of FI, (ii) the consequences of FI in children, adolescents, and adults, (iii) the current status of PA, (iv) the health effects of PA on children, adolescents, and adults, and (v) the association between FI and PA.

The current status of food insecurity

Since 1995, Economic Research Service, the U.S. Department of Agriculture (USDA), has annually conducted surveys to collect nationally representative information about FI in U.S households. In 2012, 43,942 households responded to 18 questions in the U.S. Household Food Security Survey Module (HFSSM) that was developed and validated by the USDA[1, 28]. The prevalence of FI was 14.5% or 17.6 million households. These households at times during the year had difficulty in having enough food for at least one household member because they did not have sufficient money and other assistances for food. Approximately 5.7% or 7.0 million households had very low food security that caused a reduction in food intake or disruption in eating patterns of at least one household member due to insufficient food at times during the year. The percentage of FI among U.S. households with children was 20% in 2012. Both children and adults, however, were food insecure in 10% of these households. In addition, about 1.2% of these households

had a very low food security from which at least one child reduced food intake or had a disruption in eating patterns at some time during the year[3].

Although the percentage of households with FI was little changed from 2008 (14.6%) to 2012 (14.5%), it is significantly higher than that in 1999 (10.1%). Similarly, the percentage of households with very low food security increased from 3.0% in 1999 to 5.7% in 2008 and has remained unchanged since then. For households with children, the percentage increased from 14.8% in 1999 to 17.6% in 2004 and then reduced to 15.8% in 2007 before increasing again to 21.3% in 2009. The percentage changed little between 2010 (20.2%) and 2012 (20%)[3].

Prevalence of FI differed by household characteristics. Households with married couples, without children, or with elderly had lower prevalence of FI than those with children, or with a single parent. Households led by non-Hispanic Whites had a prevalence of about two times lower than those led by non-Hispanic Blacks and Hispanics. Households with income below 185% poverty line had a prevalence of about six times higher than those with income above 185% poverty line[3].

Food insecurity consequences in children and adolescents

FI was found to be associated with child health, cognitive, social, emotional, and behavioral development in children. Casey et al. (2005) conducted a cross-sectional telephone survey among 99 children in 36 counties of Arkansas, Louisiana, and Mississippi and found lower physical function among children from three to eight years

old and lower psychosocial function among children from 12 to 17 years old living in food insecure households. Health-related quality of life of these children was also poorer than those with food security[29]. The association between FI with children's health and behavior was also reported by Dunifon et al. (2003) using data of children aged 6-12 years from the Child Development Supplement of the Panel Study of Income Dynamics in 1997. FI, however, was not associated with cognitive test scores in this study[30]. Using data from NHANES III, Alaimo et al. conducted three studies demonstrating that (i) children from six to sixteen years old living in FI households were more likely to have psychological problems, not get along well with other children, and have poorer academic performance[6]; (ii) there was a strong association between FI with depressive disorder and with suicide symptoms among children fifteen and sixteen years old[8]; and (iii) food-insufficient children were more likely to have poorer health and to have stomachaches, headaches, and colds than those with food sufficiency[31]. Similarly, another study found that poor and hungry children were more likely to have health problems such as colds, ear infections, anemia, asthma, and headaches than those poor but not hungry[32].

Using data of mothers and children from a larger case-control study, Weinreb et al. (2002) examined 180 preschool-aged and 228 school-aged children and found that both preschool- and school-aged children with severe hunger were more likely to suffer stress, chronic illness, internalizing behavior problems but not academic achievement when compared to those without hunger[33]. In addition, Cook et al. (2004) conducted a multi-site retrospective cohort study among 11,539 children under 36 months and

caregivers to find out that children living in food-insecure households were about two times more likely to have poorer health than those living in households without FI. Food secure children were also less likely to be hospitalized than those without food security[4]. Jyoti et al. (2005) also analyzed longitudinal data from the Early Childhood Longitudinal Study-Kindergarten Cohort that examined a nationally representative sample of 21,000 children from kindergarten to third grade to provide strong evidence that FI predicted developmental consequences for both boys and girls. Particularly, FI was linked to impaired social skill development and reading performance among girls[7].

In summary, children living in food insecure households are likely to experience poor general health, impaired growth, psychosocial problems, depressive disorder, and poor academic performance.

Food insecurity consequences in adults

Association between FI with poor health and with many chronic conditions such as type 2 diabetes, cardiovascular diseases, hypertension, hyperlipidemia, inflammation, psychosocial problems, and depression was investigated. Seligman et al. (2007) used 1999-2002 NHANES data of 4423 adults over 20 years old with household incomes less than 300% poverty line to investigate the association between FI and type 2 diabetes. The study showed that those with severe FI were more likely to have diabetes than those without FI. The association existed even after controlling for body mass index[9]. Using the same 1999-2002 NHANES dataset, Tayie et al. (2009) could not find the association between FI and dyslipidemia in men aged 18-50 years; the association in women was not

consistent. That is, compared to food secure women, those with marginally food security were more likely to have abnormal level of low density lipoprotein cholesterol whereas those with FI without hunger were more likely to have abnormal levels of triglyceride[12]. Seligman et al. (2010), however, found the association between FI and hyperlipidemia and also with hypertension among low-income adults aged 18-65 years by using NHANES data but waves of 1999-2004[11]. Another study by Gowda et al. (2012) using NHANES data (waves of 1999-2006) with a focus on adults aged 18 years or older found an association between FI and inflammation which is an important correlate of some chronic diseases[34].

In addition, Sharkey (2003) using the Nutrition and Function Study data examined 279 elderly women who received home-delivered meals and found that those with food insufficiency were about three times more likely to report multi-morbidity than those with food sufficiency[35]. Stuff et al. (2004) examined the association between household FI and self-reported health status in a sample of 1488 adults randomly selected in the Lower Mississippi Delta region. The findings showed that adults living in food insecure households were more likely to score lower on physical and mental health scales of the Short Form Health Survey (SF-12). They were also more likely to rate their health as poor/fair compared to those without FI[5]. Similarly, Vozoris et al. (2003) examined the association between food insufficiency and health in Canadians using data from National Population Health Survey 1996/1997 and found that those living in food insufficient households were more likely to have poor functional health, heart disease, diabetes, high

blood pressure, and food allergies. They were also more likely to suffer major depression and have poor social support than those with food sufficiency[10].

More particularly, studies were done to examine the association between FI and depression. Whitaker et al. (2006)[18] conducted a cross-sectional survey among 2870 mothers from 2001 to 2003 in 18 large U.S cities. The findings showed that the 12 month prevalence of major depressive symptoms or generalized anxiety disorder increased from 16.9% among food secure mothers to 21.0% among those with marginal food security and to 30.3% among those reporting FI. Also investigating the association among mothers, Huddleston-Casas et al. (2009)[36] used longitudinal data from "Rural Families Speak", a multi-state study of low-income families in the U.S. rural areas from 2000 to 2002. The original sample was 413 mothers who were conveniently selected. Three waves of data collection were conducted and only 184 mothers had complete data for analysis. The finding showed that there was a casual relationship between FI and depression in rural, low-income women. This conclusion, however, needs to be carefully interpreted because although analysis with imputed data was done and the results were similar, the threat of bias by missing data still exists. In addition, this result may not be generalizable to other populations. Another cohort study by Tsai et al. (2012)[20] examined the association between FI and depression among 456 people with HIV/AIDS in rural Uganda. The association was however only significant for women, not men. The relationship between FI and depression among elders was also examined. Kim and Frongillo (2007)[19] analyzed data from two longitudinal studies, the Health and Retirement Study (1996-2002) which included 9481 people above 54 years and Health

Dynamics Among the Oldest Old (1995-2002) which included 6354 people above 71 years and found a positive relationship between FI with weight and depression among these elders.

In summary, FI was associated with poor physical and mental health status, type 2 diabetes, hyperlipidemia, hypertension, and inflammation. It was also associated with depression among women and elders.

Food insecurity and obesity

During the last two decades, although many studies were conducted to examine the association between obesity and FI, the findings were inconsistent. Eisenmann et al. (2011)[15] after reviewing 16 cross-sectional and five prospective studies about this topic among children and adolescents published since the first case study report in 1995 to 2009 were unable to conclude about the relationship because of the differences in measurement among studies as well as a lack of a comprehensive FI measure. In addition, sample sizes of early studies were small preventing firm conclusions. The authors, however, found that FI and overweight/obesity co-existed in all of these studies.

A review by Larson et al. (2011)[16] also found mixed results. The authors looked at 42 studies about the association between FI and weight status among children and non-elderly adults that were published between 2000 and 2010. Although there was an association among women, it was mixed among children and men. In addition, there was little evidence from longitudinal studies to be able to conclude about a positive

correlation between FI and weight gain. The review also found limited evidence about the association between participation in National School Lunch Program and WIC program with increased risk of obesity among children. Weak evidence, however, showed that long-term participation in the food stamp program (SNAP) may be associated with increasing risk of obesity among children and men. Stronger evidence on this association was also found among women. One limitation is that many reviewed studies were cross-sectional and therefore, the temporal nature of the association could not be examined.

Franklin et al. (2011)[17] conducted another review including 19 studies published since 2005 that had participants from all age groups. In general, the evidence about the association between food security and obesity was mixed. While a positive association among women was consistent, evidence was mixed among children and adolescents. Among men, evidence was sparse. Of 19 studies, two studies showed a linear association between FI and obesity. Three other studies showed a U-shaped relation, that is, obesity increased as FI increased to a certain level and then reduced. These studies found that those with severe FI tended to have lower BMI than others.

In summary, the association between FI and obesity seems to exist among women. More evidence about the association among children, adolescents, and men is needed before a firm conclusion can be made.

The current status of physical activity

In 2008, the U.S. Department of Health and Human Services published the Physical Activity Guidelines for Americans (PAGA) based on the report by the Physical Activity Guideline Advisory Committee. The PAGA provides specific recommendations of PA levels for Americans who are six years or older. Children and adolescents aged six to 17 are recommended to do at least 60 minutes of vigorous- and moderate-intensity PA daily. They are also recommended to include at least three days a week of vigorous-intensity aerobic, muscle-strengthening, and bone-strengthening activity. Adults aged 18 or older are recommended to do at least 150 minutes a week of moderate-intensity, or 75 minutes a week of vigorous-intensity aerobic activity, or an equivalent combination of both. The activities should be performed on at least three days a week and be at least 10 minutes per bout. Adults should also do muscle-strengthening activities with moderate and vigorous intensity on at least two days a week to gain additional health benefits[23, 24].

Although many national public health surveillance systems in the U.S. collect data about PA, this information is mostly self-reported by respondents. In 2011, data from Youth Risk Behavior Surveillance showed that 49.5% high school students reported meeting PA recommendations by doing activity that increased heart rate and made them breathe hard for at least 60 minutes for at least five day a week. This is an increase after little change from 35.8% in 2005 to 37% in 2009[37]. For adults aged 18 years or older, Behavioral Risk Factor Surveillance System data showed that among the states, a median of 51.6% adults participated in at least 150 minutes a week of aerobic PA in 2011. Despite that the 2011 data were not comparable to data from previous years, the median

percentage of adult meeting the PA recommendations seems to increase over time from 47.2% in 2003 to 50.7% in 2009[38].

The National Health and Nutrition Examination Survey (NHANES), by using accelerometers to objectively measure PA, showed that the percentage of people who met the PAGA recommendation was much lower. Troiano et al. (2008) analyzed the 2003-2004 NHANES accelerometer data, and found the percentages of participants who met the PAGA recommendation were 42% for children aged 6-11 years, 8% and 7.6% for adolescents aged 12-15 years and 16-19 years respectively, and less than 5% for adults[27]. Tucker et al. (2011) using the 2005-2006 NHANES accelerometer data also calculated the percentages of adults meeting the PAGA recommendation which was 9.6%[26]. These numbers, however, may not be completely comparable due to the differences in methodology between two studies. The trend over time cannot be seen because the accelerometer data are available for only these two NHANES cycles.

The pattern of PA was different by age, gender, and race/ethnicity. The percentages of those meeting PA recommendation declined with age for both males and females. Males were more likely to be physically active than females. Non-Hispanic White Americans were also more likely to be physically active than other racial/ethnic groups. Males and females with higher level of education were more likely to physical active as well[24].

In summary, given the current data, the majority of Americans are physically inactive. People who are older, female, not Non-Hispanic White, and have lower education level are more likely to be physically inactive.

Health effects of physical activity on adults

The Physical Activity Guideline Advisory Committee in its report comprehensively reviewed evidence about the health effects of PA on adults[24]. Strong evidence from 73 reviewed studies (71 were prospective cohort studies) showed an inverse association between PA and all-cause mortality for both men and women and for different race/ethnic groups. In general, physically active people have about 30% lower risk of mortality during follow-up compared with those who are not active.

In addition, the report, in which more than 60 studies were reviewed, found strong evidence supporting an inverse association between PA and cardiovascular and coronary heart diseases for both men and women. Individuals who reported normally doing PA had 20%-30% lower risk of cardiovascular and coronary heart diseases than those who were not physically active. Benefits of PA for racial/ethnic groups other than non-Hispanic whites were also seen but the data were limited.

The report also showed an inverse relation between PA and metabolic syndrome which is characterized by abnormal levels of lipids, elevated glucose, hypertension, and abdominal obesity. This relation was similar for men and women. Although the association was seen in non-white populations, the data were limited. A similar finding

for the relation between PA and type-2 diabetes is that an increase in PA level is associated with a decrease in the risk of developing type-2 diabetes. The association exists for both men and women. Data were insufficient for non-white racial/ethnic groups.

Although PA can have benefits for stabilizing weights in a short time, little data are available about the long-term effect. With PA amount of 13 to 26 MET-hours per week (13 MET-hours per week equivalent to walking at a speed of four miles per hour for 150 minutes per week), weight stability may be expected. The report, however, noted that this wide amount, i.e., 13-26 MET-hours per week, reflects not only individual variation but also the change in dietary intake over time as PA increases.

Furthermore, the report reviewed over 100 population-based observational studies and 28 prospective cohort studies about the relationship between PA and depression. On average, cross-sectional studies found physically active individuals have 30-45% lower odds of depression symptoms than those inactive. A similar odds of 25%-40% lower among physically active individuals compared with those inactive in cohort studies but reduced to 15%-25% after controlling for other covariates. In addition, among those diagnosed with depression, PA programs can reduce the depression symptoms regardless of age, gender, and race/ethnicity.

In summary, the report showed that current evidence strongly supports the association between PA with all-cause mortality, cardiovascular and coronary heart

diseases, metabolic syndrome, type-2 diabetes, short term weight stability, and depression.

Health effects of physical activity on children and adolescents

The Physical Activity Guideline Advisory Committee report also looked at evidence about the health effects of PA in children and adolescents[24]. After reviewing ten cross-sectional studies, one prospective cohort study, 21 experimental studies, two reviews, and one meta-analysis, a positive association between PA and cardio-respiratory fitness in children and adolescents was found for both males and females. Although data were limited for non-white populations, some studies conducted in other race/ethnicity groups showed similar findings.

In addition, the report reviewed 45 cross-sectional, 21 prospective cohort, 21 experimental, and 16 training studies to find an inverse association between PA and adiposity. Overweigh/obese youth was seen to have their adiposity reduced with regularly participating in moderate to vigorous PA, but little effect on adiposity was reported for programs that were designed to improve PA among normal-weight youth.

An association between PA and cardiovascular and metabolic health was also found. After reviewing 20 cross-sectional, two prospective, and 21 experimental studies, the report concluded that a greater amount of PA is associated with better cardiovascular and metabolic health. It has not yet been able to determine the pattern of dose-response relationship.

The report also reviewed six studies about depressive symptoms and PA including three cross-sectional, one prospective and two intervention studies. The conclusion was that benefits of PA were as seen on several mental health outcomes including anxiety, depression, self-esteem, and physical self-concepts. The dose-response pattern, however, has not yet been determined because of the insufficient numbers of randomized controlled trials.

In summary, data on PA for children and adolescents are in general more limited than data for adults. Current evidence, however, supports the conclusion that PA increases physical fitness, reduced adiposity, enhanced cardiovascular and metabolic disease risk profiles, and improved depression and anxiety symptoms.

Association between food insecurity and physical activity

The association between FI and PA has not been thoroughly investigated. Literature search found only one study by Gulliford et al. (2006)[21] that looked at the association between FI and weight control behaviors among adolescents. This study was conducted in a national sample of 3067 students who were 16 years old from 29 schools in Trinidad and Tobago. Complete data from 62% or 1903 students were analyzed. Leisure-time PA was measured by only one self-reported question which was "Which one of the following statements describes you best?" Responses were "All or most of my free time is spent doing things that involve little physical effort (e.g. watching TV, doing homework, talking to friends"; "I occasionally (once or twice a week) do things in my

free time that involve some physical effort (e.g. play sport, do running/jogging, cycling, aerobics or dancing)"; "I quite often (4–6 times a week) do things in my free time that involve some physical effort"; and "I very often (7 or more times per week) do things in my free time that involve some physical effort". The finding showed that adolescents with FI were more likely to be physically inactive than those without FI.

In summary, while the links between FI and PA with chronic health outcomes were thoroughly investigated, current literature lacks studies to examine whether the link between FI and PA exists.

CHAPTER 3

METHODS

Data source

The National Health and Nutrition Examination Survey (NHANES) is a continuous

cross-sectional study designed to assess the health and nutrition status of the U.S. non-

institutionalized population. It uses a complex, multistage, and probability sampling

method to select approximately 5000 participants/year in 15 counties across the country.

A wide range of different health data was collected through face-to-face interview at

home and examination and laboratory tests in a Mobile Examination Center (MEC). All

survey materials were in English and Spanish. The NCHS Research Ethics Review Board

approved the study and informed consents were obtained. Details on design and

methodology were published elsewhere[39].

The 2006-2010 NHANES did not collect accelerometer data and 2011-2012

NHANES accelerometer data (which have not been publicly available) used a different

device and protocol, as a result only combined data from 2003-2004 and 2005-2006

NHANES was used. It may also be an advantage to use data collected before the

recession in 2008, given that many economic factors may affect FI status. Although a

total of 20,470 individuals (response rate of 79.73%) were interviewed and 19,593

(response rate of 76.68%) were examined[40], the analysis was restricted to subsamples

because the availability of the data was different by age groups and variables (Table 3.1).

For children under five years old, accelerometer data were not available. For those from 2-11 years old, self-report PA data were not available and individual food-insecurity data were from proxy respondents at the MEC. For adolescents from 12-15 years old, self-report PA data were incomplete because only leisure time PA was measured at the MEC but transportation and housework PA were not measured. Individual FI was also not administered for NHANES 2003-2004 among the adolescents. All data were available for those ≥ 16 years of age and older. Household food-insecurity data were available for all age groups as one adult answered for all members at home interview. In addition to the data availability, both children and adults sample was used because the effects of FI are different from one another and therefore, it is worthy figuring out whether their associations with PA are different.

Table 3.1: Availability of data by age groups and variables

Age	2-5	6-11	12-15	>=16
Household food insecurity	An adult answered for all members at home interview			
Individual food insecurity	Proxy respondents at MEC		Not administered for NHANES 2003-2004 But did at MEC for NHANES 2005-2006	MEC
Self-report PA - Transportation and housework	Not administered		Not administered	Administered at home interview
- Leisure time	Not administered		MEC	Administered at home interview
Accelerometer	Not administered	Worn for 7 consecutive days		

Participants with difficulty walking due to a health problem were excluded. Those older than 65 years old and pregnant women were also excluded due to a high possibility of their physical limitation. The subsample of accelerometer and FI data included those from six to 65 years of age who wore an accelerometer for ≥10 hours/day and ≥4 days/week (to be consistent with standard processing in NHANES)[26]. For analyses on self-report PA and FI, those from 16-65 years old were selected. The analysis was limited to those below 350% poverty line because FI among those above 350% poverty line is rare. The age groupings to be used, variables, the sample sizes, and missing values are in Table 3.2, Table 3.3, and Table 3.4.

Table 3.2: Age groups, variables, and the sample sizes

	Accelerometry		Self-report	
Variables	**6-17 years**	**18-65 years**	**16-17 years**	**18-65 years**
HH food insecurity	3077	4580	1091	7797
Adhere	3166	4685	1138	8030
Sedentary minutes	3166	4685	N/A	N/A
Age	3166	4685	1138	8030
Gender	3166	4685	1138	8030
Race/ethnicity	3166	4685	1138	8030
Household reference person (HHRP) marital status	3041	N/A	1091	N/A
Individual marital status	N/A	4683	N/A	8025
HHRP Education	3067	N/A	1068	N/A
Individual education	N/A	4683	N/A	8024
Household size	3166	4685	1138	8030
Family poverty income	3052	4492	1075	7602
No missing for FI and PA	3077	4580	1091	7797

Table 3.3: Age groups, variables, and sample sizes for only those with FI and PA

Variables	Accelerometry		Self-report	
	6-17 years	18-65 years	16-17 years	18-65 years
Age	3077	4580	1091	7797
Gender	3077	4580	1091	7797
Race/ethnicity	3077	4580	1091	7797
HHRP Marital status	2954	N/A	1046	N/A
Individual marital status	N/A	4578	N/A	7792
HHRP Education	3000	N/A	1044	N/A
Individual education	N/A	4578	N/A	7791
Household size	3077	4580	1091	7797
Family poverty income	2998	4415	1053	7466
No missing for all variables	**2840**	**4413**	**985**	**7462**

Table 3.4: Number of missing values for each variable

Variables	Accelerometry		Self-report	
	6-17 years	18-65 years	16-17 years	18-65 years
Age	0	0	0	0
Gender	0	0	0	0
Race/ethnicity	0	0	0	0
HHRP Marital status	123	N/A	45	N/A
Individual marital status	N/A	2	N/A	5
HHRP Education	77	N/A	47	N/A
Individual education	N/A	2	N/A	6
Household size	0	0	0	0
Family poverty income	79	165	38	331
Missing for all variables	**237**	**167**	**106**	**335**

Measures

Independent variable

Because individual FI data collection differed among NHANES cycles and age groups, household FI data were used. Household FI was measured using the U.S. Household Food Security Survey Module (HFSSM) that was developed and validated by the USDA[1, 28]. Briefly, an adult in households without children under 18 years old responded to ten questions about the frequency of "worried whether our food would run out"; "the food that we bought just didn't last"; "we couldn't afford to eat balanced meals"; "cut the size of your meals or skip meals"; "eat less than you felt you should"; "hungry but didn't eat"; "lose weight because there wasn't enough food"; "not eat for a whole day". For households with children under 18 years, eight more questions about the frequency of "relied on only a few kinds of low-cost food to feed the children"; "couldn't feed the children a balanced meal"; "the children were not eating enough"; "cut the size of any of the children's meal"; "the children ever hungry"; and "the children ever not eat for a whole day" were asked. Households were considered food secure if ≤2 questions were affirmatively responded; and food insecure if ≥3 questions were affirmatively responded[1, 28].

Outcome variable

PA was measured by both questionnaire and accelerometer. The questionnaire measured frequency and duration of PA in leisure time, household chores and yard work, and transportation. Participants were asked to indicate (1) whether they "walked or bicycled"; "had tasks around home/yard"; "had moderate physical activity"; and "had

vigorous physical activity" in bouts of ≥10 minutes over the past 30 days; (2) how many

times they performed these activities; and (3) how long each time. Further details about

the questions were published elsewhere[41]. The total minutes of transportation,

household/yard, and leisure-time activity were then calculated and classified into

"adhere" or "not adhere" based on the PAGA recommendation using a SAS program

from NHANES website[42].

ActiGraph AM-7164 accelerometers were provided to the participants after their

examination. This uni-axial Actigraph records the intensity of PA as "counts" over

periods (epochs) of one minute. The participants were asked to wear it on the right hip,

keep it dry, and remove it at bedtime for seven days. A postage-paid envelop was

provided for participants to return the device. On the return, the raw data were

downloaded, and the device was checked for calibration specifications. The raw data

were then converted to PA minutes per day and can be downloaded from NHANES

websites[9]. Further details about the accelerometer protocol can be found elsewhere[27, 42].

This study followed standard processing in NHANES in which participants with

10,080 data points (60minutes times 24hours times 7days) and whose data are reliable

and in calibration were used. Wear and non-wear time was used to identify valid days

which had the wear time of ≥10 hours. Wear time was calculated by subtracting non-wear

time from 24hours. Non-wear time was defined by a period of at least 60 consecutive

minutes with intensity counts of zero, with allowance for up to two consecutive minutes

with intensity counts between 0 and 99[27, 42].

SAS programs were downloaded from National Cancer Institute[43] and modified to calculate sedentary, moderate, and vigorous PA minutes, and to convert PA minutes per day into PA minutes per person. Intensity thresholds which were used to determine the PA intensity for different ages groups can be found elsewhere[27, 42]. Briefly, sedentary threshold=0 counts/min, light threshold=100, lifestyle threshold for adults=760, age-specific moderate thresholds for children under 18 years range from 1400 to 3239, and for adults is 2020, and vigorous thresholds for children under 18 years range from 3758 to 6751 and for adult is 5999 (Table 3.5).

Participants were categorized as "adhere" or "not adhere" based on their PA minutes. For children and adolescent (6-17 years), "adhere" were assigned if an average of 60 minutes of MVPA or more per day was done for a week. For adults (18-65 years), "adhere" were assigned if a total of at least 150 minutes of MPA or equivalent was reached and only PA bouts of 10 minutes were used[23].

Covariates

The conceptual framework by Alaimo et al. (2006)[44] was modified to guide the analysis (Figure 3.1). Covariates to be controlled in the analysis include age, gender, race/ethnicity, marital status, education, household size, and household income (as poverty income ratio). These demographic and household characteristics were common factors to be controlled in many FI studies[45-48]. As these characteristics were also associated with PA[27, 49-51], they are potential confounders and need to be controlled in this study.

Table 3.5: age-specific thresholds for children and adults

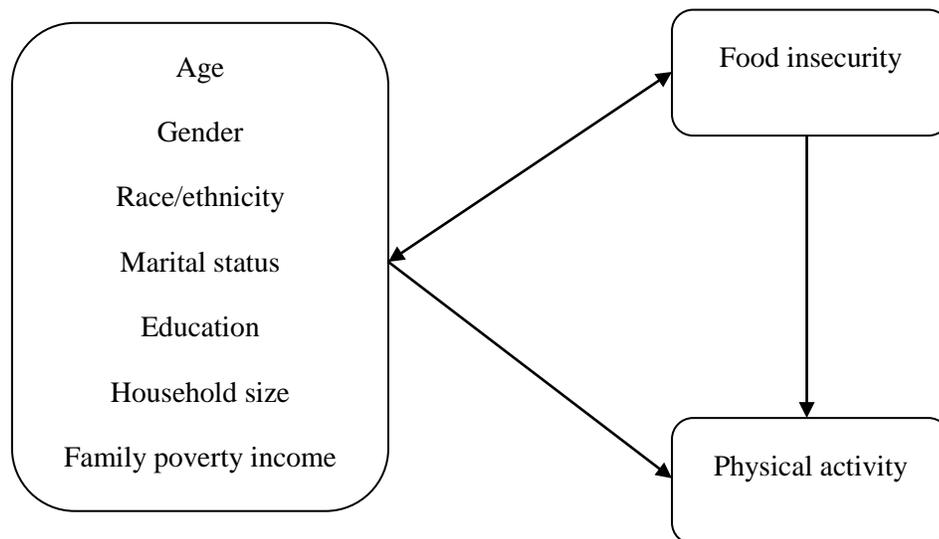| Age	Sedentary threshold	Light threshold	Lifestyle moderate threshold	Moderate threshold	Vigorous threshold
6	0	100	n/a	1400	3758
7	0	100	n/a	1515	3947
8	0	100	n/a	1683	4147
9	0	100	n/a	1770	4360
10	0	100	n/a	1910	4588
11	0	100	n/a	2059	4832
12	0	100	n/a	2220	5094
13	0	100	n/a	2393	5375
14	0	100	n/a	2580	5679
15	0	100	n/a	2781	6007
16	0	100	n/a	3000	6363
17	0	100	n/a	3239	6751
≥18	0	100	760	2020	5999

Figure 3.1: Conceptual framework

Age groups for children were "6-11 years", "12-15 years", and "16-17 years".

Adults were grouped into "18-29 years", "30-49 years", and "50-65 years". Gender was

either "male" or "female". To be consistent with standard NHANES categories and due

to small sample sizes of other racial/ethnic groups, they were combined with "Non-Hispanic White"[52].   Race/ethnicity then had three categories: "Non-Hispanic White/others", "Non-Hispanic Black", and "Mexican American". Household size was either "1-2 people", "3-4 people", "5-6 people", or "≥7 people". Poverty income ratio (PIR), which is a ratio of family income to poverty threshold given household size, was used as a continuous variable with a range of zero to five.

Individual marital status and education were used in adult analyses, and HHRP marital status and education were used in children analyses. The values for marital status were either "never married", "married", or "widowed, divorced, separated, or living with partner". The values for education were "less than high school", "high school degree", or "more than high school".

Data analyses

Analyses were conducted using SAS software, v9.3. Survey procedures in SAS were used to account for the complex survey design[42].Taylor Series Linearization methods were used for variance estimation.

As instructed by NHANES, because two NHANES cycles were combined, four-year weights were re-calculated by dividing the two-year weights by two. Four-year interview weights were used for analyses on self-report data. As we only used data from those with at least four valid days of wearing accelerometers, weights were recalculated based on the four-year MEC weights using another SAS program from NCI[53].

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Regression method was used to impute missing values for PIR based on age, gender, race/ethnicity, marital status and education, and household size. Mean and standard deviation (SD) of predicted values were compared with those of the original PIR variable. Random normal variability was added to predicted values to match the SD of the original PIR variable.

Because the PA pattern and effects of FI are different for adults and children[27, 54], two samples of children and adults were separately analyzed (Table 3.6). For the accelerometry data, outcomes were "adhere" to the PAGA recommendation (dichotomous variable), PA minutes and "sedentary minutes" (continuous variable). For the self-report dataset, the only outcome was "adhere" (dichotomous variable). The association between "adhere" and FI was tested using logistic regression. Linear regression was used to test the association between PA minutes, sedentary minutes, and FI. The covariates listed in Figure 3.1 were adjusted as categorical variables excepting PIR which is continuous.

Interactions between gender and age groups with FI were tested because the effects of FI on PA may be stronger for (i) females than males as FI females may have to spend more time with housework and have extra jobs; (ii) older children as younger children may be protected more by their parents. No significant interactions were found. Crude and adjusted odds ratio was reported for logistic regression. Coefficients were reported for linear regression.

The use of sample weights in regression analyses does not necessarily result in unbiased estimates[55] and can be statistically inefficient. An alternative is to include as covariates variables strongly related to the sampling weights such as race/ethnicity and PIR as was done in this study. Analyses were run with and without sample weights. As the results were similar, the analyses with sample weights were presented. A further robustness check was done by running the final models controlling for wear time and the results were similar. All p-values are reported in tables as two sided but one-sided p-values were considered statistically significant if <0.05 for the hypothesis that FI is associated with lower PA; these are reported in the text.

Table 3.6: Analyses for subsamples

Subsamples	FI and accelerometry	FI and self-report PA
6-15 years	1. Adhere=FI	N/A
16-17 years	2. Adhere=FI + covariates + interaction terms 3. Sedentary=FI 4. Sedentary=FI + covariates + interaction terms 5. PA minutes = FI + covariates + interaction terms	1. Adhere=FI 2. Adhere=FI + covariates + interaction terms
18-65 years	1. Adhere=FI 2. Adhere=FI + covariates + interaction terms	1. Adhere=FI 2. Adhere=FI +covariates + interaction terms
	3. Sedentary=FI 4. Sedentary=FI +covariates + interaction terms 5. PA minutes = FI + covariates + interaction terms	N/A

CHAPTER 4

FOOD INSECURITY AND PHYSICAL ACTIVITY AMONG U.S. POPULATIONS[1]

Introduction

Food insecurity (FI) is a public-health concern in the U.S. FI is defined by the Life

Sciences Research Office (LSRO) of the Federation of American Societies for

Experimental Biology as "limited or uncertain availability of nutritionally adequate and

safe foods or limited or uncertain ability to acquire acceptable foods in socially

acceptable ways"[1] or by Food and Agriculture Organization (FAO) as a situation "when

people do not have adequate physical, social or economic access to sufficient, safe and

nutritious food which meets their dietary needs and food preferences for an active and

healthy life[2]. In 2012, 14.5% or 17.6 million U.S. households were food-insecure[3].

About 5.7% or 7.0 million households had very low food security that caused at least one

household member to reduce food intake at times during the year[3].

FI is associated with poor physical and mental health outcomes among both

children and adults[4, 5]. Children living in food-insecure households were more likely to

have cognitive development deficits, behavioral and psychosocial problems, and poorer

general health[4, 6-8].Similarly, FI adult are more likely to have type 2 diabetes,

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[1] To QG, Frongillo EA, Gallegos D, Moore JB. To be submitted to the American Journal of Public Health

cardiovascular diseases, hypertension, hyperlipidemia, and inflammation[9-13].The association between FI with obesity, however, is not consistent across studies or subpopulations[14]. Eisenmann et al. (2011) reported mixed results with positive, negative, and null associations after reviewing 21 studies[15]. The review of Larson et al. (2011) also found mixed results among children and men but positive association among women[16]. Franklin et al. (2012) reviewed 19 studies since 2005 and found a strong positive association among women but mixed results among children[17]. FI was also found to be associated with depression among mothers[18], elders[19] and HIV infected women[20].

FI may affect these health outcomes by causing changes in metabolism and behavior including selecting foods with high energy, overeating when food is available, and stress and anxiety[6, 21, 22]. FI may also cause changes in physical activity (PA) behaviors. Due to lack of healthy food, it is possible that FI people are less physiologically and psychologically energetic and therefore less likely to do PA and more likely to have poorer health. The relationship between FI and PA, however, has not been thoroughly investigated. We have found only one study on this relationship; in that study, adolescents with FI were less physically active than those with food security[21]. Only one question, which asked about the frequency of spending free time doing things involving physical effort, was used to measure PA.

Investigating the association of FI with PA is important because low PA is itself a public-health concern in the U.S. and other countries facing high rates of chronic disease. While strong evidence shows numerous physical and mental health benefits of PA such as lower risks of cardiovascular diseases, diabetes, reduced depression, and obesity[23, 24], PA level among U.S. populations is low[25-27]. The Physical Activity Guidelines for Americans(PAGA)[23] recommend that adults should total at least 150 minutes/week of moderate intensity (MPA), or 75 minutes/week of vigorous intensity physical activity (VPA), or an equivalent combination of both (MVPA), and that children and adolescents should do for at least 60 minutes daily. Accelerometer data, however, showed that less than 10% of adults and adolescents[26, 27] met the PAGA. The percentage was 42% for children 6-11years[27].

This study, therefore, aimed to examine the association between FI and PA in the U.S. population. We hypothesized that FI people are less likely to adhere to the PAGA recommendation and more likely to be sedentary than those without FI.

Methods

Data source

The National Health and Nutrition Examination Survey (NHANES) is a continuous cross-sectional study designed to assess the health and nutrition status of the U.S. non-institutionalized population. It uses a complex, multistage, and probability sampling method to select about 5000 participants/year in 15 counties across the country. A wide range of different health data was collected through face-to-face interview at

home and examination and laboratory tests in a Mobile Examination Center (MEC). All survey materials were in English and Spanish. The NCHS Research Ethics Review Board approved the study and informed consents were obtained. Details on design and methodology were published elsewhere[39].

Because 2006-2010 NHANES did not collect accelerometer data and 2011-2012 NHANES accelerometer data (which have not been publicly available) used a different device and protocol, only combined data from 2003-2004 and 2005-2006 NHANES was used. It may also be an advantage to use data collected before the recession in 2008, given that many economic factors may affect FI status. Although a total of 20,470 individuals (response rate of 79.73%) were interviewed and 19,593 (response rate of 76.68%) were examined[40], the analysis was restricted to subsamples because the availability of the data was different by age groups and variables. For children under five years old, accelerometer data were not available. For those from 2-11 years old, self-report PA data were not available and individual food-insecurity data were from proxy respondents at the MEC. For adolescents from 12-15 years old, self-report PA data were incomplete because only leisure time PA was measured at the MEC but transportation and housework PA were not measured. Individual FI was also not administered for NHANES 2003-2004 among the adolescents. All data were available for those ≥ 16 years old. Household food-insecurity data were available to all age groups as one adult answered for all members at home interview. In addition to the data availability, both children and adults sample was used because the effects of FI are different from one

another and therefore, it is worthy figuring out whether their associations with PA are different.

Participants with difficulty walking due to a health problem were excluded. Those >65 years old and pregnant women were also excluded due to a high possibility of their physical limitation. The subsample of accelerometer and FI data included those from 6-65 years old who wore an accelerometer for ≥10 hours/day and ≥4 days/week (to be consistent with standard processing in NHANES)[26]. For analyses on self-report PA and FI, those from 16-65 years old were selected. The analysis was limited to those below 350% of the poverty line because FI among those above 350% of the poverty line is rare.

Measures

Independent variable

Because individual FI data collection differed among NHANES cycles and age groups, household FI data were used. Household FI was measured using the U.S. Household Food Security Survey Module (HFSSM) that was developed and validated by the USDA[1, 28]. Briefly, an adult in households without children under 18 years old responded to ten questions about the frequency of "worried whether our food would run out"; "the food that we bought just didn't last"; "we couldn't afford to eat balanced meals"; "cut the size of your meals or skip meals"; "eat less than you felt you should"; "hungry but didn't eat"; "lose weight because there wasn't enough food"; "not eat for a whole day". For households with children under 18 years, eight more questions about the frequency of "relied on only a few kinds of low-cost food to feed the children"; "couldn't

feed the children a balanced meal"; "the children were not eating enough"; "cut the size

of any of the children's meal"; "the children ever hungry"; and "the children ever not eat

for a whole day" were asked. Households were considered food secure if ≤2 questions

were affirmatively responded; and food insecure if ≥3 questions were affirmatively

responded[1, 28].

Outcome variable

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measured frequency and duration of PA in leisure time, household chores and yard work,

and transportation. Participants were asked to indicate (1) whether they "walked or

bicycled"; "had tasks around home/yard"; "had moderate physical activity"; and "had

vigorous physical activity" in bouts of ≥10 minutes over the past 30 days; (2) how many

times they performed these activities; and (3) how long each time. Further details about

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"adhere" or "not adhere" based on the PAGA recommendation using a SAS program

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ActiGraph AM-7164 accelerometers were provided to the participants after their

examination. This uni-axial Actigraph records the intensity of PA as "counts" over a one

minute epoch. The participants were asked to wear it on the right hip, keep it dry, and

remove it at bedtime for seven days. A postage-paid envelop was provided for

participants to return the device. On the return, the raw data were downloaded, and the

device was checked for calibration specifications. The raw data were then converted to PA minutes per day and can be downloaded from NHANES websites[9]. Further details about the accelerometer protocol can be found elsewhere[27, 42].

This study followed standard processing in NHANES in which participants with 10,080 data points (60minutes times 24hours times 7days) and whose data are reliable and in calibration were used. Wear and non-wear time was used to identify valid days which had the wear time of ≥10 hours. Wear time was calculated by subtracting non-wear time from 24hours. Non-wear time was defined by a period of at least 60 consecutive minutes with intensity counts of zero, with allowance for up to two consecutive minutes with intensity counts between 0 and 99[27, 42].

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Covariates

The conceptual framework by Alaimo et al. (2006)[44] was modified to guide the analysis. Covariates to be controlled in the analysis include age, gender, race/ethnicity, marital status, education, household size, and household income (as poverty income ratio). These demographic and household characteristics were common factors to be controlled in many FI studies[45-48]. Because they were also associated with PA[27, 49-51], they are potential confounders and need to be controlled in this study.

Age groups for children were "6-11 years", "12-15 years", and "16-17 years". Adults were grouped into "18-29 years", "30-49 years", and "50-65 years". Gender was either "male" or "female". To be consistent with standard NHANES categories and due to small sample sizes of other racial/ethnic groups, they were combined with "Non-Hispanic White"[52]. Race/ethnicity then had three categories: "Non-Hispanic White/others", "Non-Hispanic Black", and "Mexican American". Household size was either "1-2 people", "3-4 people", "5-6 people", or "≥7 people". Poverty income ratio (PIR), which is a ratio of family income to poverty threshold given household size, was used as a continuous variable with range 0 to 5.

Individual marital status and education were used in adult analyses, and HHRP marital status and education were used in children analyses. The values for marital status were either "never married", "married", or "widowed, divorced, separated, or living with partner". The values for education were "less than high school", "high school degree", or "more than high school".

Data analyses

Analyses were conducted using SAS software, v9.3. Survey procedures in SAS were used to account for the complex survey design[42].Taylor Series Linearization methods were used for variance estimation.

As instructed by NHANES, because two NHANES cycles were combined, four-year weights were re-calculated by dividing the two-year weights by two. Four-year interview weights were used for analyses on self-report data. Because we only used data from those with at least four valid days of wearing accelerometers, weights were recalculated based on the four-year MEC weights using another SAS program from NCI[53].

Regression method was used to impute missing values for PIR based on age, gender, race/ethnicity, marital status and education, and household size. Mean and standard deviation (SD) of predicted values were compared with those of the original PIR

variable. Random normal variability was added to predicted values to match the SD of the original PIR variable.

Because the PA pattern and effects of FI are different for adults and children[27, 54], two samples of children and adults were separately analyzed. For the accelerometry data, outcomes were "adhere" to the PAGA recommendation (dichotomous variable), PA minutes and "sedentary minutes" (continuous variable). For the self-report dataset, the only outcome was "adhere" (dichotomous variable). The association between "adhere" and FI was tested using logistic regression. Linear regression was used to test the association between PA minutes, sedentary minutes and FI. The covariates were adjusted as categorical variables excepting PIR which is continuous.

Interactions between gender and age groups with FI were tested because the effects of FI on PA may be stronger for (i) females than males as FI females may have to spend more time with housework and have extra jobs; (ii) older children as younger children may be protected more by their parents. No significant interactions were found. Crude and adjusted odds ratio was reported for logistic regression. Coefficients were reported for linear regression.

The use of sample weights in regression analyses does not necessarily result in unbiased estimates[55] and can be statistically inefficient. An alternative is to include as covariates variables strongly related to the sampling weights such as race/ethnicity and PIR as was done in this study. Analyses were run with and without sample weights. As

the results were similar, the analyses with sample weights were presented. A further robustness check was done by running the final models controlling for wear time, and the results were similar. All p-values are reported in tables as two sided but one-sided p-values were considered statistically significant if <0.05 for the hypothesis that FI is associated with lower PA are reported in the text.

Results

Characteristics of the samples

There were a total of 2261 children in the accelerometry sample (PAM) (Table 4.1). About a half of children (49.65%) were age 6-11 years, 36.35% were age 12-15 years, and 14% age 16-17 years. Less than a half (48.02%) was girls. A majority (63.23%) was non-Hispanic White/others; non-Hispanic Black and Mexican American had similar percentages of about 18%. About a quarter (25.55%) was living with a household reference person (HHRP) who had a level of education less than high school; 28.81% had high school degree and 45.64% had an education level higher than high school. A majority of HHRP (64.76%) was married; only 9.80% was never married. Most of the households had 3-4 people (43.72%) or 5-6 people (40.58%). Average poverty income ratio was 1.67 which means, on average, family income was about 167% of the poverty line. More than a quarter (26.62%) of children was living in food-insecure households. Only about a third (31.10%) met the PA level recommended by the PAGA. On average, a child was sedentary for 410.63 minutes per day.

The total number of children who were 16-17 years old in the self-reported PA sample (PAQ) was 788. The percentage of girls was 48.56%. A majority of children (65.84%) was non-Hispanic White/others; about a fifth (19.91%) was non-Hispanic Black and 14.25% was Mexican American. The percentage of children living with a HHRP with an education level of less than high school was 25.62%; 30% had a high school degree and 44.35% had an education level higher than high school. More than a half (56.67%) was married; 10.21% was never married. About a half (49.76%) was living in households of 3-4 people; another 31.25% was living in households of 5-6 people. On average, family income was 172% of the poverty line. The percentage of household FI was 22.54%. Most children (75.22%) self-reported meeting the PA level recommended by the PAGA.

The total number of adults in the PAM sample was 2712 (Table 4.2). One third (33.54%) were age 18-29 years, nearly a half (45.79%) were age 30-49 years and one fifth (20.67%) were age 50-65 years. More than a half (50.47%) were females. Most of adults (71.07%) were non-Hispanic White/others; non-Hispanic Black and Mexican American had the percentages of 15% for non-Hispanic Black and 13.93% for Mexican American. The percentage of adults with an education level less than high school, high school, or higher than high school were respectively 21.46%, 29.81%, and 48.73%. About a half (47.82%) were married while 26.56% was never married. The majority of the sample was living in a household of 1-2 people (33.18%) or 3-4 people (39.72%); only 5.46% was living with more than seven people. The average family income was 187% of the poverty line. The percentage of household with food insecurity was 18.90%.

Only 6.12% met PA level recommended by the PAGA. On average, adults were

sedentary for 452.95 minutes per day.

Table 4.1: Characteristics of child sample for PAM and PAQ

Children	PAM		PAQ	
	N	% or mean (SE)	N	% or mean (SE)
Age group				
6-11	957	49.65	n/a	n/a
12-15	909	36.35	n/a	n/a
16-17	395	13.99	788	100
Gender (female)	1119	48.02	361	48.56
Race				
NH White/others	582	63.23	207	65.84
NH Black	794	18.66	310	19.91
Mexican American	885	18.10	271	14.25
HHRP Education				
Less than high school	826	25.55	307	25.62
High school grad	595	28.81	200	30.02
More than high school	780	45.64	243	44.35
HHRP Marital status				
Never married	303	9.80	119	10.21
Married	1281	64.76	395	56.67
Others	567	25.44	233	33.12
Household size				
1-2	82	3.89	47	7.82
3-4	817	43.72	329	49.76
5-6	946	40.58	265	31.25
>=7	416	11.81	147	11.18
Poverty Income Ratio (mean)	2254	1.67 (0.04)	783	1.72 (0.04)
HH Food insecurity				
HH food security	1529	73.45	553	77.46
HH food insecurity	732	26.55	235	22.54
PA Adherence (Yes)	654	31.10	580	75.22
Sedentary minutes/day (mean)	2261	410.63 (4.18)	n/a	n/a

The total number of adults in the PAQ sample was 4886. One third (33.43%) were aged 18-29 years; 45.51% were age 30-49 years; and 21.06% were age from 50-65 years. About a half (50.92%) were female. Most (70.87%) were non-Hispanic White/others; 15.60% and 13.53% were respectively non-Hispanic Black and Mexican American. The percentage of adults with a degree higher than high school was largest (45.01%); 30.22% had a high school degree; and 24.77% did not complete high school. Nearly a half (45.40%) was married whereas 28.10% was never married. A majority of adults was living in households of 1-2 people (33.04%) or 3-4 people (39.60%); 21.50% in households of 5-6 people; only 5.86% in households of 7 people or more. Average family income was 181% of the poverty line. Nearly one fifth (19.51%) was living in food-insecure households. More than a half (58.14%) self-reported meeting the PAGA recommendation.

Association between physical activity and food insecurity in children

From logistic regression models run with accelerometry data to examine the association between FI and PA in children age 6-17 years, children who lived in food-insecure households were about 0.92 times less likely to adhere to the PAGA recommendation (Table 4.3). The association was not significant (one-sided p-values) in both crude (p=0.285) and adjusted (p=0.347) models.

Similar results were found with self-report data in children aged 16-17 years old (Table 4.4). Those living in food-insecure households were less likely (0.828 times in the

crude model and 0.921 in the adjusted model) to adhere to the PAGA recommendation, but the association was not significant (one-sided p=0.200 and 0.386, respectively).

Table 4.2: Characteristics of adult sample for PAM and PAQ

Adult	PAM		PAQ	
	N	% or mean (SE)	N	% or mean (SE)
Age group				
18-29	923	33.54	2046	33.43
30-49	1101	45.79	1817	45.51
50-65	688	20.67	1023	21.06
Gender (female)	1316	50.47	2405	50.92
Race				
NH White/others	1204	71.07	2128	70.87
NH Black	678	15.00	1355	15.60
Mexican American	830	13.93	1403	13.53
Education				
Less than high school	896	21.46	1741	24.77
High school grad	751	29.81	1370	30.22
More than high school	1063	48.73	1769	45.01
Marital status				
Never married	816	26.56	1776	28.10
Married	1222	47.82	1914	45.40
Others	673	25.62	1193	26.50
Household size				
1-2	827	33.18	1443	33.04
3-4	1040	39.72	1894	39.60
5-6	618	21.65	1119	21.50
>=7	227	5.46	430	5.86
Poverty Income Ratio (mean)	2699	1.87 (0.03)	4845	1.81 (0.03)
HH Food insecurity				
HH food security	2085	81.10	3728	80.49
HH food insecurity	627	18.90	1158	19.51
PA Adherence (Yes)	208	6.12	2804	58.14
Sedentary minutes/day (mean)	2712	452.95 (2.95)	n/a	n/a

Table 4.3: Logistic regression models between FI and PA adherence for PAM in children aged 6-17 years

Model 1 (n=2261)	OR	p-value
Food insecurity (yes vs. no)	0.928	0.570
Model 2 (n=2098)	**OR**	**p-value**
Food insecurity (yes vs. no)	0.927	0.695
Age 12-15 vs. 6-11	0.053	0.116
Age 16-17 vs. 6-11	0.006	**<0.001**
Female vs. male	0.374	**<0.001**
Mexican American vs. NH White/others	1.255	0.594
NH Black vs. NH White/others	1.295	0.473
High school vs. above high school	0.621	0.062
Below high school vs. above high school	0.752	0.766
Married vs. others	1.022	0.348
Never married vs. others	1.742	0.092
HH size 1-2 vs. ≥7	0.397	0.122
HH size 3-4 vs. ≥7	0.589	0.445
HH size 5-6 vs. ≥7	0.801	0.232
PIR	1.139	0.220

Reference was: not adhere to physical activity recommendation
Model 1: include only food insecurity
Model 2: adjusted for age, gender, race/ethnicity, education, marital status, household size, and PIR

Association between physical activity and food insecurity in adults

From logistic regression models run to examine the association between FI and PA in adults, adults living in food-insecure households were less like to adhere to the PAGA recommendation (crude OR=0.948 for accelerometry and 0.715 for self-report data, Table 4.5). The association was significant only for self-report data (p<0.001). After adjusting for demographic and household characteristics, the OR was 0.722 for accelerometry and 0.839 for self-report data. The associations were significant (one-sided p-value) for both accelerometry (p=0.033) and self-report data (p=0.005).

Table 4.4: Logistic regression models between FI and PA adherence for PAQ in children aged 16-17 years

Model 1 (n=788)	OR	p-value
Food insecurity (yes vs. no)	0.828	0.400
Model 2 (n=714)	**OR**	**p-value**
Food insecurity (yes vs. no)	0.921	0.772
Age 16 vs. 17	2.084	**0.003**
Female vs. male	0.393	**0.001**
Mexican American vs. NH White/others	0.683	0.547
NH Black vs. NH White/others	0.686	0.389
High school vs. above high school	0.834	0.862
Below high school vs. above high school	0.776	0.584
Married vs. others	1.682	0.823
Never married vs. others	2.493	0.054
HH size 1-2 vs. ≥7	0.689	0.533
HH size 3-4 vs. ≥7	0.984	0.499
HH size 5-6 vs. ≥7	0.717	0.516
PIR	0.987	0.922

Reference was: not adhere to physical activity recommendation
Model 1: include only food insecurity
Model 2: adjusted for age, gender, race/ethnicity, education, marital status, household size, and PIR

Association between sedentary minutes and food insecurity

From linear regression models run with accelerometry data to examine the association between FI and sedentary minutes in children, children living in food-insecure households, on average, had 12.04 minutes of sedentary activities more than those without FI (Table 4.6). The association was not significant (one-sided p=0.068). After adjusting for demographic and household characteristics, children living in food-insecure households, on average, had significantly more (10.74) sedentary minutes than those without FI (one-sided p-value 0.032). The association between FI and sedentary minutes in adults was not significant (one-sided p-values) in both crude (p=0.135) and adjusted models (p=0.289) (Table 4.7)

Table 4.5: Logistic regression models between FI and PA adherence in adults

	PAM-adhere (yes vs. no)			PAQ-adhere (yes vs. no)		
	N	OR	p-value	N	OR	p-value I
Model 1	2712			4886		
Food insecurity (yes vs. no)		0.948	0.795		0.715	**<0.001**
Model 2	2696			4839		
Food insecurity (yes vs. no)		0.722	**0.066**		0.839	**0.011**
Age 18-29 vs. 50-65		1.514	0.090		1.606	**0.000**
Age 30-49 vs. 50-65		1.133	0.737		1.172	0.377
Female vs. male		0.576	**0.003**		0.860	0.068
Mexican American vs. NH White/others		1.584	0.114		0.620	**<0.001**
NH Black vs. NH White/others		1.370	0.680		0.871	0.262
High school vs. above high school		0.775	**0.010**		0.670	0.843
Below high school vs. above high school		1.668	**0.001**		0.466	**<0.001**
Married vs. others		1.280	0.371		0.895	0.043
Never married vs. others		2.304	**0.006**		1.169	0.067
HH size 1-2 vs. ≥7		1.862	**0.006**		0.989	0.347
HH size 3-4 vs. ≥7		0.916	0.059		0.998	0.419
HH size 5-6 vs. ≥7		1.041	0.552		1.255	**0.032**
PIR		0.854	0.257		1.050	0.263

Model 1: include only food insecurity

Model 2: adjusted for age, gender, race/ethnicity, education, marital status, household size, and PIR

Table 4.6: Linear regression models between FI and sedentary minutes in children aged 6-17 years

	Coefficient	p-value
Model 1 (n=2261)		
Food insecurity (yes vs. no)	12.04	0.136
Model 2 (n=2098)		
Food insecurity (yes vs. no)	10.74	**0.063**
Age 12-15 vs. 6-11	113.86	**<0.001**
Age 16-17 vs. 6-11	152.36	**<0.001**
Female vs. male	23.16	**<0.001**
Mexican American vs. NH White/others	13.74	**0.027**
NH Black vs. NH White/others	29.24	**<0.001**
High school vs. above high school	-3.05	0.707
Below high school vs. above high school	-12.37	0.194
Married vs. others	-7.67	0.313
Never married vs. others	-7.51	0.566
HH size 1-2 vs. ≥7	22.08	0.213
HH size 3-4 vs. ≥7	2.76	0.769
HH size 5-6 vs. ≥7	7.57	0.335
PIR	-1.19	0.766

Reference was: not adhere to physical activity recommendation

Model 1: include only food insecurity

Model 2: adjusted for age, gender, race/ethnicity, education, marital status, household size, and PIR

Association between PA minutes and food insecurity

Food-insecure children did significantly less MVPA than did food-secure children (adjusted coefficient = -5.31, p = 0.032) (Table 4.8). Food-insecure adults did more light PA minutes (adjusted coefficient = 2.40, p = 0.649), more MVPA in bouts of less than 10 minutes (adjusted coefficient = 0.32, p = 0.723), and less in bouts of ≥10 minutes (adjusted coefficient = -0.89, p =0.187) but these associations were not significant.

Table 4.7: Linear regression models between FI and sedentary minutes in adults aged 18-65 years

	Coefficient	p-value
Model 1 (n=2712)		
Food insecurity (yes vs. no)	-7.13	0.271
Model 2 (n=2696)		
Food insecurity (yes vs. no)	3.54	0.578
Age 18-29 vs. 50-65	-32.25	**0.002**
Age 30-49 vs. 50-65	-39.49	**<.0001**
Female vs. male	-0.13	0.981
Mexican American vs. NH White/others	-37.04	**<.0001**
NH Black vs. NH White/others	19.97	**0.014**
High school vs. above high school	-37.99	**<.0001**
Below high school vs. above high school	-42.72	**<.0001**
Married vs. others	-4.61	0.510
Never married vs. others	29.15	**0.008**
HH size 1-2 vs. ≥7	18.97	0.219
HH size 3-4 vs. ≥7	6.83	0.617
HH size 5-6 vs. ≥7	12.70	0.426
PIR	-1.75	0.658

Reference was: not adhere to physical activity recommendation
Model 1: include only food insecurity
Model 2: adjusted for age, gender, race/ethnicity, education, marital status, household size, and PIR

Table 4.8: Linear regression models between FI and PA minutes

	Model 1		Model 2	
	Coefficient	p-value	Coefficient	p-value
Children				
Light PA		N/A		
MVPA	-2.65	0.276	-5.31	**0.032**
Adults				
Light PA	3.32	0.454	1.37	0.740
Light + lifestyle moderate PA	5.98	0.323	2.40	0.649
MVPA (<10m)	0.66	0.433	0.32	0.723
MVPA (>10m)	0.10	0.888	-0.89	0.187

Model 1: include only food insecurity
Model 2: adjusted for adjusted for age, gender, race/ethnicity, education, marital status, household size, and PIR

Discussion

Children living in food-insecure households were not less likely to adhere to the PAGA recommendation, but these children were more sedentary than children living in food-secure households and engaged in less MVPA. Adults living in food-insecure households were less likely to adhere to the PAGA recommendation but were not more sedentary than adults living in food-secure households.

The estimates of association of FI with PA in children were smaller in magnitude but in the same direction as in adults, i.e., food-insecure children tended to be less likely to adhere to the PAGA recommendation. One possible explanation for the smaller association is the high level of PA among children: food-insecure children were less physically active than food-secure children but their PA level was still high enough to meet the PAGA recommendation. It is also possible that food-secure children did more light PA than those with FI (Figure 4.1).
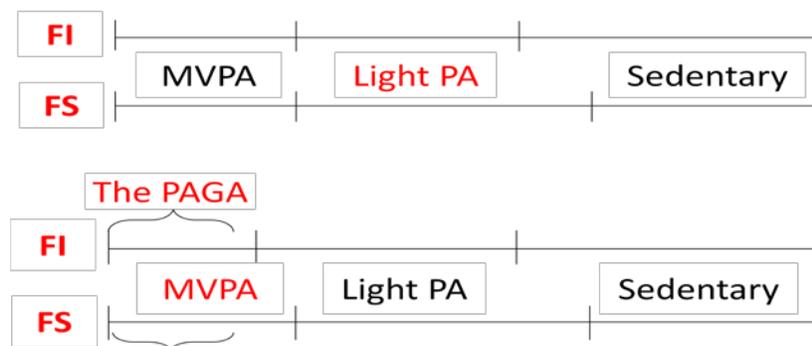

Figure 4.1 Possible explanations for the results in children

It is unclear why food-insecure adults were less likely to adhere to the PAGA recommendation but were not more sedentary than those with food security. It is possible that, because of FI, adults were less physically and psychologically strong and therefore, they tend to do PA with lighter intensity and/or in shorter bouts (i.e. less than 10 minutes) which were not counted toward the total minutes (Figure 4.2).
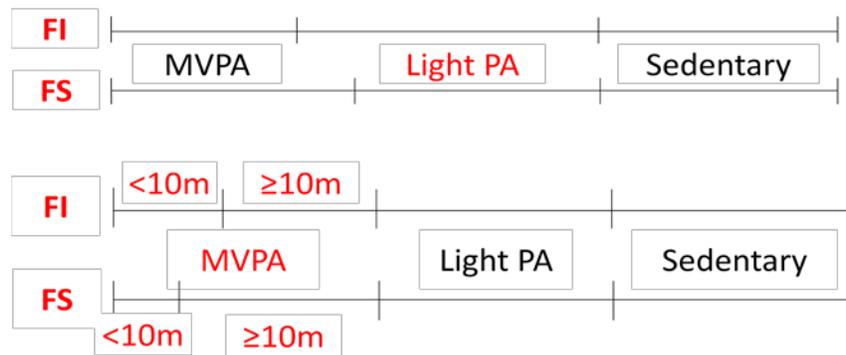

Figure 4.2 Possible explanations for the results in adults

The much lower percentages of children and adults adhering to the PAGA recommendation in the PAM compared to the PAQ sample may reflect the possibility of PAM underestimating the amount PA due to not accurately capturing upper body and non-locomotor activities[26] and of PAQ overestimating the amount of PA due to social desirability, recall bias, and reporting all activities including those less than bouts of ten minutes[26, 56]. That both of these measures showed the same result strengthens our finding about the association between FI and PA.

Two possible mechanisms operating in opposite directions could explain the association observed between FI and PA. First, FI could lead to nutrient insufficiency,

distress, and poorer health, and therefore less PA and more sedentary behavior. Second, lower PA and higher sedentary behavior could lead to poorer general health, higher health cost, lower work productivity, and therefore being unable to afford enough food. In children, the first mechanism may be more likely because food is typically provided by caregivers. Furthermore, it is unlikely that children's PA would affect household FI, and if it did, the effect would likely be that higher child PA leads to more household FI rather than less. In adults, it is possible that the two mechanisms operate simultaneously. Although, the former explanation seems more plausible than the latter because family income was controlled in the analyses, given the cross-sectional data in this study and the complexity of the mechanisms, it is impossible to make any causal inference

This is one of the first studies investigating the association between FI and PA in the U.S. population. We used NHANES data which are high in quality and represent the U.S. population. PA was not only measured by self-report but also objectively by accelerometers. The study, however, has some limitations. The samples did not cover all ethnic groups well and the results may not be generalized to other ethnic groups such as Asians. The uni-axial accelerometers which were worn on the hip may not capture upper-body physical activities. Recall bias may happen with self-reported PA. Sample size was small for the PAQ sample of children aged 16-17 years. Causal inference was impossible for cross-sectional data. Finally, using household FI may not completely reflect the individual FI in the household, especially for children[57, 58].

Conclusion

Children living in food-insecure households were more sedentary and less moderately-vigorously active, but not less likely to adhere to the PAGA recommendation, than those living in food-secure households. Adults living in food-insecure households were less likely to adhere to the PAGA recommendation, but not more sedentary, than those living in food-secure households.

These findings suggest that PA should be considered when studying and explaining relationships between FI and health outcomes. The interventions that improve FI may have indirect effects on health outcomes through improving PA and reducing sedentary behaviors in children and adults.

Future research may investigate this relationship in other ethnic groups such as Asians. More research is also needed to confirm the causal relationship between FI and PA. Further investigation into the mechanism through which FI differently influences PA and sedentary behaviors in children and adults is important to provide a deeper understanding on the issue, and to be able to design more effective interventions improving FI and PA in the U.S.

CHAPTER 5

SUMMARY, IMPLICATIONS AND RECOMMENDATIONS

Children who lived in food-insecure households were about 0.92 times (both PAM and PAQ) less likely to adhere to the PAGA recommendation, but the associations were not significant. Children living in food-insecure households, on average, had about 11 minutes of sedentary activities more, and 5 minutes of moderate-to-vigorous activity less, than those without FI

Adults who lived in food-insecure households were 0.72 times (PAM) and 0.84 times (PAQ) less like to adhere to the PAGA recommendation, and the associations were significant. Adults living in food-insecure households, on average, had about 3 minutes of sedentary activities more than those without FI, but the association was not significant.

PA needs to be considered when studying and explaining relationships between FI and health outcomes. The effectiveness of FI interventions may also include indirect effects on health outcomes through improving the PA level and reducing sedentary behaviors in both children and adults.

Future research may investigate this relationship in other ethnic groups such as Asians. More research is also needed to confirm the causal relationship between FI and PA. Further investigation into the mechanism through which FI differently influences PA and sedentary behaviors in children and adults is important to provide a deeper understanding on the issue, and to be able to design more effective interventions improving FI and PA in the U.S.

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