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Household Food Insecurity Is Associated with Less Physical Activity among Children and Adults in the U.S. Population[1,2]

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Abstract

Background: Household food insecurity and physical activity are each important public-health concerns in the United States, but the relation between them has not been investigated thoroughly.

Objective: This study aimed to examine the association between food insecurity and physical activity in the U.S. population.

Methods: Physical activity measured by accelerometry (PAM) and physical activity measured by questionnaire (PAQ) data from the NHANES 2003–2006 were used. Individuals aged <6 y or >65 y, pregnant women, individuals with physical limitations, and individuals with family income >350% of the poverty line were excluded. Food insecurity was measured by the USDA Household Food Security Survey Module. Adjusted ORs were calculated from logistic regression to identify the association between food insecurity and adherence to the physical-activity guidelines. Adjusted coefficients were obtained from linear regression to identify the association between food insecurity with sedentary/physical-activity minutes.

Results: In children, food insecurity was not associated with adherence to physical-activity guidelines measured via PAM or PAQ and with sedentary minutes ($P > 0.05$). Food-insecure children did less moderate to vigorous physical activity than food-secure children (adjusted coefficient = -5.24, $P = 0.02$). In adults, food insecurity was significantly associated with adherence to physical-activity guidelines (adjusted OR = 0.72, $P = 0.03$ for PAM; and OR = 0.84, $P < 0.01$ for PAQ) but was not associated with sedentary minutes ($P > 0.05$).

Conclusions: Food-insecure children did less moderate to vigorous physical activity, and food-insecure adults were less likely to adhere to the physical-activity guidelines than those without food insecurity. J. Nutr. 144: 1797–1802, 2014.

Introduction

Food insecurity is a public-health concern in the United States. Food insecurity is defined 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). In 2012, 14.5% or 17.6 million U.S. households were food insecure (2). Approximately 5.7% or 7 million households had very low food security that caused ≥1 household member to reduce food intake at times during the year (2).

Food insecurity is associated with poor physical and mental health outcomes among children and adults (3,4). Children living in food-insecure households were more likely to have cognitive development deficits, behavioral and psychosocial problems, and poorer general health (3,5–7). Food-insecure adults were more likely to have type 2 diabetes, cardiovascular diseases, hypertension, hyperlipidemia, and inflammation (8–12). Food insecurity was also found to be associated with depression among mothers (13), elders (14), and HIV-infected women (15). However, the association between food insecurity with obesity is not consistent across studies or subpopulations (16). A review of 21 studies in children and adolescents reported mixed results of negative, null, and positive associations between food insecurity and obesity (17). Two other reviews found mixed results among children and men but positive association among women (18,19).

Food insecurity 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 (5,20,21). Food insecurity may also cause changes in physical activity behaviors. Because of the lack of healthy food or uncertainty in accessing it, it is possible that food-insecure people are less physiologically and psychologically energetic and therefore less likely to do physical activity and more likely to have poorer health. However, the relation between food insecurity and physical activity was not thoroughly investigated. In the 1 study we found on this relation, adolescents experiencing food insecurity were less physically active than those with food security (20). Only 1 question, which asked about the frequency of spending free time doing things involving physical effort, was used to measure physical activity.

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Investigating the association of food insecurity with physical activity is important because food insecurity may be a risk factor for physical inactivity, and interventions focused on food-insecure individuals may increase the prevalence of physically active individuals. Furthermore, low physical activity is itself a public-health concern in the United States. Although strong evidence shows numerous physical and mental health benefits of physical activity, such as lower risks of cardiovascular diseases, diabetes, depression, and obesity (22,23), the physical activity amount in the U.S. population is low (24–26). The Physical Activity Guidelines for Americans (PAGA)[5] (22) recommend that adults should total ≥150 min/wk moderate physical activity, 75 min/week vigorous physical activity, or an equivalent of moderate to vigorous physical activity (MVPA) and that children and adolescents should be physically active for ≥60 min daily. However, accelerometer data showed that <10% of adults and adolescents (25,26) met the PAGA. The percentage was 42% for children aged 6–11y (26).

Therefore, this study aimed to examine the association between food insecurity and physical activity in the U.S. population. We hypothesized that food-insecure children and adults were less likely to adhere to the PAGA recommendation and more likely to be sedentary than those without food insecurity.

Methods

Data source

The 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 multistage, probability sampling method to select ~5000 participants/y in 15 counties across the country. A wide range of health data were collected through face-to-face interviews at home and examination and through laboratory tests in a mobile examination center. Survey materials were in English and Spanish. The National Center for Health Statistics Research Ethics Review Board approved the study, and informed consents were obtained. Details on the design and methodology were published previously (27).

The NHANES 2003–2004 and 2005–2006 have data on both physical activity measured by accelerometry (PAM) and physical activity measured by questionnaire (PAQ), which were combined and used (n = 20,470). For PAM, those wearing an accelerometer for ≥10 h/d and ≥4 d/wk (to be consistent with standard processing in the NHANES) (25) were included (n = 9750). Data on investigated variables were available for people aged 6–65 y (n = 8115 for PAM and 16–65 y (n = 9833 for PAQ). Pregnant women (n = 264 for PAM and n = 665 for PAQ) were excluded because of the possibility of physical limitations. Analyses were limited to those below 350% of the poverty line (2405 excluded for PAM and 2861 for PAQ) because food insecurity is rare among those above 350%. Those with missing food insecurity or physical activity data (n = 177 for PAM and n = 251 for PAQ) were excluded. Participants with difficulty walking because of a health problem (n = 296 for PAM and n = 382 for PAQ) were also excluded. The final PAM sample was 2261 children and 2712 adults. The final PAQ sample was 788 children and 4886 adults.

Measures

Exposure variable. Because individual food insecurity data collection differed among the NHANES cycles and age groups, household food insecurity data were used. Household food insecurity was measured using the U.S. Household Food Security Survey Module developed and validated by the USDA (1,28). An adult in households without children aged <18 y responded to 10 items about the frequency of the following: *1*) "worried whether our food would run out"; *2*) "the food that we bought just didn't last"; *3*) "we couldn't afford to eat balanced meals"; *4*) "cut the size of your meals or skip meals"; *5*) "eat less than you felt you should"; *6*) "hungry but didn't eat"; *7*) "lose weight because there wasn't enough food"; and *8*) "not eat for a whole day." For households with children aged <18 y, 8 more items were asked about the frequency of the following: *1*) "relied on only a few kinds of low-cost food to feed the children"; *2*) "couldn't feed the children a balanced meal"; *3*) "the children were not eating enough"; *4*) "cut the size of any of the children's meal"; *5*) "the children ever hungry"; and *6*) "the children ever not eat for a whole day." Households were considered food secure if ≤2 items were affirmed and food insecure if ≥3 items were affirmed (1,28).

Outcome variables. Physical activity was measured by questionnaire and accelerometer. The questionnaire measured frequency and duration of physical activity in leisure time, household chores and yard work, and transportation. Participants were asked to indicate the following: *1*) whether they "walked or bicycled," "had tasks around home/yard," "had moderate physical activity," and "had vigorous physical activity" in bouts of ≥10 min over the past 30 d; *2*) how many times they performed these activities; and *3*) how long each time. Additional details about the questions were published previously (29). 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 (22) using a SAS program from the NHANES website (30).

ActiGraph AM-7164 accelerometers were provided to the participants after their examination. This uni-axial actigraph records the intensity of physical activity as "counts" over periods (epochs) of 1 min. The participants were asked to wear it for 7 d on the right hip, to keep it dry, and to remove it at bedtime. A postage-paid envelope 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 physical activity minutes per day and can be downloaded from the NHANES website (8). Additional details about the accelerometer protocol were published previously (26,30).

This study followed standard processing in the NHANES in which participants with 10,080 data points (60 min × 24 h × 7 d) and whose data were reliable and in calibration were used. Wear and non-wear time was used to identify valid days that had the wear time of ≥10 h. Wear time was calculated by subtracting non-wear time from 24 h. Non-wear time was defined as a period of ≥60 consecutive minutes with intensity counts of 0, with allowance for up to 2 consecutive minutes with intensity counts between 0 and 99 (26,30).

SAS programs were downloaded from the National Cancer Institute (31) and modified to calculate sedentary, light, lifestyle moderate, moderate, and vigorous physical activity minutes and to convert physical activity minutes per day into physical activity minutes per person. Intensity thresholds that were used to determine the physical activity intensity for different ages groups were published previously (26,30). Briefly, sedentary threshold is 0 counts/min, light threshold is 100 counts/min, and lifestyle threshold for adults is 760 counts/min. Age-specific moderate thresholds for children under 18 y range from 1400 to 3239 and for adults is 2020. Vigorous thresholds for children under age 18 y range from 3758 to 6751 and for adults is 5999.

Participants were categorized as "adhere" or "not adhere" based on their physical activity minutes. For children and adolescents (6–17 y), "adhere" was assigned if a mean of ≥60 min/d MVPA was done for 1 wk. For adults (18–65 y), "adhere" was assigned if a total of ≥150 min of moderate physical activity or equivalent was reached, and only physical activity bouts of 10 min were used (22).

Covariates. The conceptual framework by Alaimo et al. (32) was modified to guide the analysis. Covariates include age, gender, race/ethnicity, marital status, education, household size, and household income. These covariates were controlled in many food-insecurity studies (33–36). Because these covariates were also associated with physical activity

[5] Abbreviations used: HHRP, household reference person; HS, high school; MVPA, moderate to vigorous physical activity; PAGA, Physical Activity Guidelines for Americans; PAM, physical activity measured by accelerometry; PAQ, physical activity measured by questionnaire; PIR, poverty income ratio.

(26,37–39), they are potential confounders that needed to be controlled in this study.

Age groups for children were 6–11, 12–15, and 16–17 y. Adults were grouped into 18–29, 30–49, and 50–65 y. Gender was either male or female. Race/ethnicity had 3 categories: *1*) non-Hispanic white; *2*) non-Hispanic black; and 3) Mexican-American/others. Household size was either 1–2, 3–4, 5–6, or ≥7 individuals. The poverty income ratio (PIR), which is the ratio of family income to the poverty threshold given household size, was used as a continuous variable with a range of 0–5.

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

Data analyses

Analyses were conducted using SAS software (version 9.3; SAS Institute). Survey procedures were used to account for the complex survey design (30). Taylor series linearization methods were used for variance estimation.

As instructed by the NHANES, because 2 NHANES cycles were combined, 4-y weights were recalculated by dividing the 2-y weights by 2. Four-year interview weights were used for analyses on PAQ. Because we only used data from those with ≥4 valid days of wearing accelerometers, weights were recalculated based on the 4-y mobile examination center weights using another SAS program from the National Cancer Institute (31).

Linear regression was used to impute missing values for PIR based on age, gender, race/ethnicity, marital status, education, and household size. Means ± SDs 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. The imputation for PIR was necessary because the percentage of missing values was >5%.

Because the physical activity patterns and associations with food insecurity were expected to differ for adults and children (26,40), children and adults were analyzed separately. For PAM, outcomes were adhere to the PAGA recommendation (dichotomous variable), physical activity minutes, and sedentary minutes (continuous variables). For PAQ, the only outcome was adhere (dichotomous variable). The association between adhere and food insecurity was tested using logistic regression. Linear regression was used to test the association between physical activity minutes, sedentary minutes, and food insecurity. The covariates were adjusted as categorical variables except PIR, which was continuous.

Interactions between gender and age groups with food insecurity were tested because the association of food insecurity with physical activity may be stronger for the following: *1*) females more than males, because food-insecure females may have to spend more time with housework and have extra jobs; and *2*) older children, because younger children may be protected more by their parents. No statistically significant interactions were found. ORs were 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 (41) 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. Because the results were similar, the analyses with sample weights are presented. An additional robustness check was done by running the final models controlling for wear time, and the results were similar. Because our hypothesis was that food insecurity is associated with lower physical activity, 1-sided P values are reported and were considered statistically significant if <0.05.

Results

Approximately one-half of the children in PAM were girls, non-Hispanic whites, and aged 6–11 y (**Table 1**). One-quarter of the children had the HHRP with an education of less than high school (HS). A majority of the HHRP was married. Most households had 3–4 or 5–6 individuals. Mean PIR was 1.67, indicating that, on average, family income was 167% of the poverty line; approximately one-quarter were living in food-insecure households. For physical activity, approximately one-third met the PAGA recommendation, and, on average, a child did 58.3 min of MVPA and was sedentary for 410.6 min/d.

TABLE 1 Characteristics of child samples for PAM and PAQ data[1]

Characteristics	PAM	PAQ
Age group (y)		
6–11	49.7 (957)	—
12–15	36.4 (909)	—
16–17	14.0 (395)	100 (788)
Gender, *% female*	48.0 (1119)	48.6 (361)
Race		
Non-Hispanic white	50.3 (413)	55.7 (158)
Non-Hispanic black	18.7 (794)	19.9 (310)
Mexican-American/others	31.0 (1054)	24.43 (320)
HHRP education		
Less than high school	25.6 (826)	25.6 (307)
High school graduate	28.8 (595)	30.0 (200)
More than high school	45.6 (780)	44.4 (243)
HHRP marital status		
Never married	9.8 (303)	10.2 (119)
Married	64.8 (1281)	56.7 (395)
Others	25.4 (567)	33.1 (233)
Household size (individuals)		
1–2	3.9 (82)	7.8 (47)
3–4	43.7 (817)	49.8 (329)
5–6	40.6 (946)	31.3 (265)
≥7	11.8 (416)	11.2 (147)
Poverty income ratio	1.67 ± 0.04 (2254)	1.72 ± 0.04 (783)
Household food security status		
Secure	73.5 (1529)	77.5 (553)
Insecure	26.6 (732)	22.5 (235)
PA adherence, *% yes*	31.1 (654)	75.2 (580)
Time sedentary, *min/d*	410.6 ± 4.2 (2261)	—
Time of MVPA, *min/d*	58.3 ± 1.2 (2261)	—

[1] All values are percentages or means ± SEs; *n* in parentheses. HHRP, household reference person; MVPA, moderate to vigorous physical activity; PA, physical activity; PAM, physical activity measured by accelerometry; PAQ, physical activity measured by questionnaire.

Approximately one-half of the children in the PAQ were girls and non-Hispanic white. A one-quarter of the children had the HHRP with an education of less than HS. More than one-half of the HHRP were married. Approximately one-half were living in households of 3–4 individuals. On average, family income was 172% of the poverty line; one-fifth of the households were food insecure. Most children self-reported meeting the PAGA recommendation.

One-third of adults in PAM were aged 18–29 y, and one-half were females (**Table 2**). A majority were non-Hispanic white. Adults with an education level less than HS were approximately one-fifth; fewer than half were married. The majority was living in a household of 1–2 or 3–4 individuals. The mean family income was 187% of the poverty line. Food-insecure households were less than one-fifth. For physical activity, less than one-tenth met the PAGA recommendation. On average, adults were sedentary for 452.9 min and did 274.7 min of light physical activity, 376.2 min of light and lifestyle moderate physical

TABLE 2 Characteristics of adult samples for PAM and PAQ data[1]

Characteristics	PAM	PAQ
Age group (y)		
18–29	33.5 (923)	33.4 (2046)
30–49	45.8 (1101)	45.5 (1817)
50–65	20.7 (688)	21.1 (1023)
Gender, *% female*	50.5 (1316)	50.9 (2405)
Race		
Non-Hispanic white	58.0 (964)	58.7 (1680)
Non-Hispanic black	15.0 (678)	15.6 (1355)
Mexican-American/others	27.0 (1070)	25.7 (1851)
HHRP education		
Less than high school	21.5 (896)	24.8 (1741)
High school graduate	29.8 (751)	30.2 (1370)
More than high school	48.7 (1063)	45.0 (1769)
HHRP marital status		
Never married	26.6 (816)	28.1 (1776)
Married	47.8 (1222)	45.4 (1914)
Others	25.6 (673)	26.5 (1193)
Household size (individuals)		
1–2	33.2 (827)	33.0 (1443)
3–4	39.7 (1040)	39.6 (1894)
5–6	21.7 (618)	21.5 (1119)
≥7	5.5 (227)	5.9 (430)
Poverty income ratio	1.87 ± 0.03 (2699)	1.81 ± 0.03 (4845)
Household food security status		
Secure	81.1 (2085)	80.5 (3728)
Insecure	18.9 (627)	19.5 (1158)
PA adherence, *% yes*	6.1 (208)	58.1 (2804)
Time sedentary, *min/d*	452.9 ± 2.9 (2712)	—
Time of light PA, *min/d*	274.7 ± 2.2 (2712)	—
Time of light plus lifestyle moderate PA, *min/d*	376.2 ± 3.0 (2712)	—
Time of MVPA, *min/d*		
Bouts < 10 min	20.9 ± 0.4 (2712)	—
Bouts ≥ 10 min	6.6 ± 0.4 (2712)	—

[1] All values are percentages or means ± SEs; *n* in parentheses. HHRP, household reference person; MVPA, moderate to vigorous physical activity; PA, physical activity; PAM, physical activity measured by accelerometry; PAQ, physical activity measured by questionnaire.

activity, 20.9 min of MVPA (bouts of <10 min), and 6.6 min of MVPA (bouts of ≥10 min) per day.

One-third of adults in PAQ were aged 18–29 y. Half were female. A majority were non-Hispanic white. For education, approximately one-quarter did not complete HS, and fewer than one-half were married. A majority was living in households of 1–2 or 3–4 individuals. Mean family income was 181% of the poverty line; approximately one-fifth of the households were food insecure. More than one-half self-reported meeting the PAGA recommendation.

The percentage of physical activity adherence for children living in food-secure and food-insecure households differed by 3.6% for PAQ and 0.6% for PAM (**Table 3**). Children living in food-secure households, on average, were less sedentary by ~12 min and had ~3 min more of MVPA than those in food-insecure households. The percentage of physical activity adherence for adults living in food-secure and food-insecure households differed by 8.3% for PAQ and 0.3% for PAM. Adults living in food-secure households, on average, were more sedentary by ~7 min and had ~3 min less of light physical activity, 6 min less of light and lifestyle moderate physical activity, 1 min less of MVPA (bouts of <10 min), and similar MVPA (bouts of ≥10 min).

The association between physical activity adherence and food insecurity was not significant in children for either PAM (adjusted OR = 0.94, $P = 0.37$) or PAQ (adjusted OR = 0.91, $P = 0.37$) (**Table 4**). The association was significant in adults (adjusted OR = 0.72, $P = 0.03$ for PAM; and adjusted OR = 0.84, $P = 0.01$ for PAQ).

The associations of MVPA with food insecurity were significant in children (adjusted coefficient = −5.24, $P = 0.02$), but the association of sedentary minutes with food insecurity was not significant ($P = 0.07$) (**Table 5**). In adults, the associations between physical activity and sedentary minutes with food insecurity were not significant (adjusted coefficient = 3.27, $P = 0.31$ for sedentary minutes; adjusted coefficient = 1.74, $P = 0.34$ for light physical activity; adjusted coefficient = 3.37, $P = 0.27$ for light and lifestyle moderate physical activity; adjusted coefficient = 0.42, $P = 0.32$ for MVPA in bouts of <10 min; and adjusted coefficient = −0.90, $P = 0.08$ for MVPA in bouts of ≥10 min).

Discussion

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

TABLE 3 Weighted percentages and means of PA outcomes by food insecurity in children and adults[1]

Variables	Food insecurity	Food security
Children		
PAM		
PA adherence		
No	70.1 (519)	68.5 (1088)
Yes	29.9 (213)	31.5 (441)
Time sedentary, *min/d*	419.5 ± 6.9 (732)	407.4 ± 4.8 (1529)
Time of light PA, *min/d*	—	—
Time of MVPA, *min/d*	56.3 ± 2.2 (732)	59.0 ± 1.4 (1529)
PAQ		
PA adherence		
No	27.6 (61)	24.0 (147)
Yes	72.4 (174)	76.0 (406)
Adults		
PAM		
PA adherence		
No	94.1 (584)	93.8 (1920)
Yes	5.9 (43)	6.2 (165)
Time sedentary, *min/d*	447.2 ± 5.4 (627)	454.3 ± 3.4 (2085)
Time of light PA, *min/d*	277.4 ± 3.6 (627)	274.0 ± 2.6 (2085)
Time of light plus lifestyle moderate PA, *min/d*	381.0 ± 4.5 (627)	375.1 ± 3.7 (2085)
Time of MVPA, *min/d*		
Bouts < 10 min	21.5 ± 0.8 (627)	20.8 ± 0.5 (2085)
Bouts ≥ 10 min	6.7 ± 0.7 (627)	6.6 ± 0.5 (2085)
PAQ		
PA adherence		
No	48.5 (541)	40.2 (1541)
Yes	51.5 (617)	59.8 (2187)

[1] All values are percentages or means ± SEs; *n* in parentheses. MVPA, moderate to vigorous physical activity; PA, physical activity; PAM, physical activity measured by accelerometry; PAQ, physical activity measured by questionnaire.

TABLE 4 Logistic regression models between food insecurity (exposure variable) and PA guideline adherence (outcome variable)[1]

Variables	*n*	OR (95% CI)	*P*
Children			
PAM[2] (PA adherence vs. non-adherence)	2098	0.94 (0.68, 1.29)	0.37
PAQ[3] (PA adherence vs. non-adherence)	714	0.91 (0.57, 1.45)	0.37
Adults			
PAM (PA adherence vs. non-adherence)	2696	0.72 (0.55, 0.96)	0.03
PAQ (PA adherence vs. non-adherence)	4839	0.84 (0.74, 0.94)	<0.01

[1] Food security is the reference. ORs are for food insecure divided by food secure, adjusted for age, gender, race/ethnicity, education, marital status, household size, and poverty income ratio. PA, physical activity; PAM, physical activity measured by accelerometry; PAQ, physical activity measured by questionnaire.
[2] Sample of children aged 6–17 y.
[3] Sample of children aged 16–17 y.

were not more sedentary than adults living in food-secure households.

The estimates of the association of food insecurity with physical activity adherence 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. As shown in the analysis on MVPA minutes, the weaker association may be attributable to the high amount of physical activity among children: food-insecure children were less physically active than food-secure children, but their physical activity amount was still high enough to meet the PAGA recommendation. It is also possible that food-secure children did more light physical activity than those with food insecurity, but data on light physical activity minutes were unavailable for analysis.

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 food insecurity, adults were less physically and psychologically strong, and therefore, they tend to do physical activity with lighter intensity and/or in shorter bouts (i.e., <10 min) that were not counted toward the total minutes. Although the analyses on light physical activity and MVPA minutes (in bouts of <10 and ≥10 min) showed that the estimates were in the same direction as explained, the associations were not significant.

The much lower percentages of children and adults adhering to the PAGA recommendation in PAM than PAQ may reflect the possibility of PAM underestimating the amount of physical activity as a result of not accurately capturing upper-body and non-locomotor activities (25) and of PAQ overestimating the amount of physical activity because of social desirability, recall bias, and reporting all activities, including those bouts of <10 min (25,42). That both of these measures showed the same result strengthens our finding about the association between food insecurity and physical activity.

Two possible mechanisms operating in opposite directions could explain the association observed between food insecurity and physical activity. First, food insecurity could lead to nutrient insufficiency, distress, and poorer health and, therefore, a lesser amount and lower intensity of physical activity. Second, a lesser amount and lower intensity of physical activity could lead to poorer general health, higher health costs, 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 physical activity would affect household food insecurity, and, if it did, the effect would likely be that higher child physical activity leads to more household food insecurity rather than less. In adults, it is possible that the 2 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 not possible to make any causal inference. Furthermore, it is possible that the association between food insecurity and physical activity is driven by an unaccounted variable that causes both and/or that food insecurity is a marker of general material hardship beyond income.

This is 1 of the first studies investigating the association between food insecurity and physical activity in the U.S. population. We used NHANES data, which are high in quality and represent the U.S. population. Physical activity was not only measured by self-report but also objectively by accelerometers. However, the study 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 physical activity. The sample size was small for the PAQ sample of children. Using household food insecurity may not completely reflect the individual food insecurity in the household, especially for children (43,44).

Children living in food-insecure households were less moderately-to-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 were not more sedentary than those living in food-secure households. These findings suggest that physical activity should be considered when studying and explaining relations between food insecurity and health outcomes. The interventions that improve food insecurity may have indirect effects on health outcomes through improving physical activity and reducing sedentary behaviors in children and adults.

Future research may investigate this relation in other ethnic groups. More research is also needed to confirm the causal relation between food insecurity and physical activity. Additional investigation into the mechanism through which food insecurity differently influences physical activity 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 to reduce food insecurity and increase physical activity in the United States.

TABLE 5 Linear regression models between food insecurity (exposure variable) with sedentary and PA minutes (outcome variables)[1]

Variables	*n*	Coefficient	*P*
Children			
Light PA	—	—	—
Sedentary	2098	8.87	0.07
MVPA	2098	−5.24	0.02
Adults			
Sedentary	2696	3.27	0.31
Light PA	2573	1.74	0.34
Light plus lifestyle moderate PA	2573	3.37	0.27
MVPA (<10 min)	2573	0.42	0.32
MVPA (≥10 min)	2573	−0.90	0.08

[1] Coefficients represent differences in minutes for food insecure minus food secure, adjusted for age, gender, race/ethnicity, education, marital status, household size, and poverty income ratio. MVPA, moderate to vigorous physical activity; PA, physical activity.

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