

Height differences and the associations between food insecurity, percentage body fat and BMI among men and women

Francis A Tayie^{1,*} and Claire A Zizza²

¹Department of Human Environmental Studies, 1150 S. Washington Street, 205 Wightman Hall, Central Michigan University, Mount Pleasant, MI 48859, USA; ²Department of Nutrition and Food Science, Auburn University, Auburn, AL 36849, USA

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Abstract

Objective: The present study examined the associations between adult food insecurity (FI) and percentage body fat (%BF) and BMI, stratified by height (HT).

Design, setting and subjects: %BF, HT and BMI of 2117 men and 1909 women in the National Health and Nutrition Examination Survey 1999–2002 were analysed in relation to adult food security status using multiple regression procedures.

Results: Compared with the fully food-secure, men's %BF, BMI and HT were lower as FI intensified. Marginal food security among women was associated with 1.3 cm shorter HT, $P = 0.016$. Marginal food security among women who were below median HT was associated with about 2.0 kg/m² higher BMI, $P = 0.042$. %BF was not associated with FI among women.

Conclusions: FI is associated with shorter HT and lower %BF and BMI in men. Women's HT should be considered in the reported associations between FI and higher BMI.

Keywords
Body mass index
Food insecurity
Height
Percentage body fat

Between 1995 and 2006, the prevalence of adult food insecurity (FI), defined as having limited or uncertain availability of nutritionally adequate and safe foods or limited or uncertain ability to acquire acceptable foods in socially acceptable ways⁽¹⁾, fluctuated between 9.5 and 11.9%⁽²⁾ in the USA. Several research reports indicate that food-insecure individuals are at higher risk of overweight and obesity (OWOB) and obesity-related health problems^(3,4). Intermediate levels of FI are associated with higher BMI in women^(5–7) and in some cases men^(5,8). These associations have been observed to vary by the level and severity of FI⁽⁹⁾. The mechanisms responsible for the positive association between FI and BMI in women have not been established but several plausible explanations have been offered, including socio-economic deprivation, adaptive coping behaviour and lack of access to resources^(7,10–12). However, these are characteristics indicative of low socio-economic status, which is associated with shorter height (HT)^(13–15).

To our knowledge, nutritional indicators that reflect earlier life experiences, such as HT, have not been documented among food-insecure adults living in the USA. Short HT arising from inadequate nutrition has been observed in developing countries for several decades^(14,16). Long-term nutritional deficiencies among vulnerable populations such as the food-insecure engender HT deficits in adults^(13,16). Inadequate nutrition can result

in inadequate intakes of nutrients essential for linear growth, including iodine, Zn, Ca, vitamin A, protein and energy, one consequence of which is HT deficits in adults^(16,17). Studies show that people who experience undernutrition at a young age recover in weight but not in HT^(13,18,19).

Bioelectrical impedance analysis (BIA) is one method used for the assessment of percentage body fat (%BF)^(20–22). Whereas researchers have examined the associations between FI and OWOB using BMI, to our knowledge none have examined the associations using %BF derived from BIA. If a positive association exists between FI and BMI among women, a positive association between FI and %BF in women would be expected. The purpose of the present study was to examine the associations between FI and %BF and BMI, and whether these associations vary by HT.

Methods

Study sample and data sources

Cross-sectional data from the National Health and Nutrition Examination Survey (NHANES) 1999–2002 were used for the present study. The NHANES is a nationally representative survey conducted by the National Center for Health Statistics (NCHS) of the Centers for Disease

*Corresponding author: Email tayie1f@cmich.edu

Control and Prevention. Stratified, multistage probability cluster sampling methods were used in the NHANES. It is an ongoing survey that covers the non-institutionalized US civilian population.

Because prior researchers have reported associations between FI and OWOB in adults, those 18–50 years of age were selected for the present analysis. In addition, this age range was selected because body composition and HT vary markedly in younger and older persons^(23,24) and the use of BMI to assess adiposity in older adults has been questioned^(25,26).

From the baseline sample of 4048 who had complete BIA and food security data in the NHANES 1999–2002, a total of 4026 (99.46%) subjects comprising 2117 men and 1909 women were included after meeting various inclusion criteria, i.e. has complete data on age, body weight, food security status, gender and HT, and not having extremely low or extremely high %BF. Twenty-two subjects, comprising 0.54% of the baseline sample, did not satisfy the inclusion criteria and thus were excluded from analysis. Of the twenty-two subjects who did not meet the inclusion criteria, two subjects had missing data for body weight. Six and fourteen had extremely low and high %BF respectively, were clear outliers and thus were excluded from the study. The NCHS Ethics Review Board approved the survey protocols and informed consent was obtained from all subjects. The procedures for the present study were approved locally by the Institutional Review Board, Office of Human Subjects Research, Auburn University, Alabama.

Food security measure

In the NHANES 1999–2002, depending on the number of affirmative answers to a subset of ten items pertaining to adults from the core eighteen-item US food security survey module, subjects were assigned to one of four food security levels: (i) fully food-secure; (ii) marginal food security (affirmative answers to one or two of the questions about food security, suggesting a risk for FD); (iii) food-insecure without hunger (reported uncertainty about food supply, a need to adapt food management strategies or indicative of a decrease in diet quality); or (iv) food-insecure with hunger (both quality and quantity of food decreased to the extent that there was repeated experience of the physical sensations of hunger)^(2,8). Food security questions asked during the survey referred to food-related circumstances in the past 12 months prior to administration of the food security questionnaire⁽²⁾.

Body fat and height assessment

A bioimpedance spectrum analyser (HYDRA ECF/ICF 4200; Xitron Technologies, Inc., San Diego, CA, USA) was used for BIA, which involved tetrapolar measurement of whole-body electrical resistance. In the NHANES 1999–2002, BIA examinations were conducted by trained health technicians in the mobile examination centres (MEC)⁽²⁷⁾. In the present study, BIA values at 50 kHz

electrical current were used to estimate fat-free body mass (FFM) by utilizing a prediction equation for adult men and women which has been validated against dual-energy X-ray absorptiometry⁽²²⁾. Utilizing this equation⁽²²⁾, fat-free mass was estimated as:

$$\text{FFM} = -4.104 + (0.518 \times H^2/R) + (0.231 \times \text{weight}) \\ + (0.130 \times \text{reactance}) + (4.229 \times \text{gender; males} \\ = 1, \text{females} = 0),$$

where H^2/R is HT squared divided by resistance (cm^2/Ω). From the estimated FFM, the %BF was calculated as follows⁽²⁸⁾:

$$\%BF = [(\text{body weight} - \text{FFM}) \div \text{body weight}] \times 100.$$

%BF values were calculated separately for men and women. Subjects who were measured in the BIA sample in the NHANES 1999–2002 were within the ages 18–50 years.

In the NHANES 1999–2002, HT was measured by trained technicians using a stadiometer equipped with an integrated survey information system⁽²⁹⁾. Further details on HT and other anthropometric measurements are available elsewhere⁽²⁹⁾.

Statistical analysis and covariates

To correct for MEC sampling design and to apply MEC sampling weights⁽³⁰⁾, the STATA statistical software package version 10.0 (StataCorp., College Station, TX, USA) was used to estimate all descriptive and inferential statistics. Due to reported differences in the association between FI and body weight status between men and women, all analyses were stratified by gender^(5,10).

For categorical data, Pearson's χ^2 test of independence with Rao and Scott correction was used, whereas for continuous variables, the overall *F* test was used to test for significant bivariate associations across levels of food security^(31,32).

Multiple linear regression models were used to examine the associations between FI and %BF, BMI and HT. In multiple linear regression models, second-order interaction terms of FI and HT were tested (Wald *F* test) to determine if HT modified the association between FI and BMI. Because the interaction terms were significant, we stratified the FI models for %BF and BMI by HT. We stratified subjects into those below median HT and median HT or taller as follows for this sample: (i) for men, below median HT was <174.7 cm and median HT or taller was ≥ 174.7 cm; and (ii) for women, below median HT was <161.7 cm and median HT or taller was ≥ 161.7 cm.

Covariates included in all multiple linear regression models were age, education, ethnicity/race, income and smoking status because of reported associations with body weight^(13,33,34). Age, %BF, BMI, HT and income were examined as continuous variables whereas education, ethnicity and smoking status were examined as indicator variables. Level of education was classified as less than high school degree and high school degree or

higher. Due to small sample sizes, race/ethnicity was collapsed into three categories: Black non-Hispanic; Mexican-American and other Hispanics; and White non-Hispanic plus others. In the NHANES 1999–2002, respondents who reported they currently smoked at least 100 cigarettes, a pipe twenty times and a cigar twenty times in their lifetime were classified as current smokers. Others who reported previous smoking were classified as ex-smokers. Those who reported never smoking to all were classified as never smokers.

In testing for associations between the main exposure variable (food security status) and the outcome variables (%BF, BMI and HT), the fully food-secure category was the referent group and did not include the marginal food security category. The significance of the independent association of FI was assessed by means of a *t* test on the β coefficients. In all statistical tests, significant differences were tested at $P < 0.05$.

Results

Sample characteristics

Background characteristics of the subjects are presented in Table 1. Of the 4026 subjects in the study, 52% were men and 48% were women. Subjects who were fully food-secure made up 82.01% of this sample. The mean BMI of the subjects was 26.76 (SE 0.10) kg/m² for men and 27.41 (SE 0.24) kg/m² for women. The other characteristics of the subjects across the four levels of food security are shown in Table 1.

Percentage body fat, BMI and height

There was significant interaction between food security status and HT in the association between FI and BMI as indicated by the adjusted Wald test, $P < 0.038$. This result indicates that the trends in the association between FI and BMI were different at different levels of HT.

Table 2 shows the %BF of men and women by food security status. Men who were food-insecure without hunger or with hunger had significantly lower %BF than men who were fully food-secure. This pattern did not change after HT stratification in men (Table 3). Compared with fully food-secure women, FI was not significantly associated with %BF among women, not even after HT stratification (Table 3).

Men who were food-insecure without hunger or with hunger had significantly lower BMI than men who were fully food-secure (Table 2), irrespective of HT (Table 3). Different patterns of association were observed among women. Before HT stratification, there was only a marginally significant positive association between FI and BMI (Table 2) among women. However, after HT stratification, women who were marginally food-secure and were below median HT had an approximately 2 kg/m² higher BMI compared with their fully food-secure

counterparts, $P = 0.042$ (Table 3). Compared with their fully food-secure counterparts, no significant differences in BMI were observed among women who were of median HT or taller.

Men who experienced FI without and with hunger had significantly shorter HT by about 2 cm compared with fully food-secure men. Among women, marginal food security was associated with approximately 1.3 cm shorter HT, $P = 0.016$. Although insignificant, there was a tendency for women in the other food-insecure categories to be shorter than their fully food-secure counterparts.

Discussion

A significant finding in the present study is that women who were marginally food-secure and were below median HT had significantly higher BMI, but women who were of median HT or taller did not. Although not statistically significant, BMI showed a tendency towards higher values among food-insecure women who were below median HT. Among women, no association was found between FI and %BF which is a more sensitive measure of adiposity. Our results indicate that, unlike BMI, %BF did not vary by HT among women. The importance of HT in FI and BMI analysis was observed earlier and included as a control variable in a study which reported a moderate ($P = 0.06$) but positive association between FI and BMI⁽¹¹⁾. Our results suggest that HT should be considered when examining the association between FI and BMI.

We observed that marginal food security was associated with shorter HT in women. In the case of men, it was the extreme forms of FI, food-insecure without and with hunger, which were significantly associated with shorter HT. The observation that FI was associated with shorter HT among men and women was not unexpected because HT deficits result from chronic under-nutrition^(14,16), which is a possible consequence of FI. It was difficult to glean from available data whether women who were below median HT in the present study had experienced FI for a longer duration than those who were of median HT or taller. However, an earlier report indicated that about two-thirds of food-insecure persons in the USA experience FI as recurring while one-fifth experience it as frequent or chronic⁽³⁵⁾.

Low-income individuals, who largely include those who are food insecure, are associated with shorter HT^(13,15), probably due to difficulties in obtaining optimum nutrition during their growing years^(14,16,36). Ensuring adequate nutrition by alleviating FI would improve adult HT and perhaps help to ameliorate its influence on the development and progression of obesity. Improvement in adult HT is exigent because several disease risks have been associated with short HT in adults. Short adult HT is associated with risk of CHD and stroke mortality^(31,37).

Table 1 Background characteristics of the study sample by adult food security status and gender

Characteristic	Men						Women										
	Fully food-secure (n 1573)		Marginally food-secure (n 187)		Food-insecure without hunger (n 234)		Food-insecure with hunger (n 123)		Fully food-secure (n 1432)		Marginally food-secure (n 204)		Food-insecure without hunger (n 175)		Food-insecure with hunger (n 98)		
	%	se#	%	se#	Mean	se##	Mean	se##	Mean	se##	Mean	se##	Mean	se##	Mean	se##	
Ethnicity*																	
White (non-Hispanic)‡	76.92		39.76		46.22		58.81*		76.40		48.54*		46.62*		68.05*		
Black (non-Hispanic)	9.28		23.08		18.08		11.98		10.40		22.63*		17.27*		11.89		
Hispanic§	13.80		37.16		35.70		29.21		13.19		28.82		36.11		20.06		
Level of education*																	
Less than high school	15.75		41.50*		49.94*		48.18*		85.08		69.44*		64.40*		66.45*		
High school or greater	84.25		58.50		50.06		51.82		14.92		30.56		35.60		33.55		
Marital status*																	
Married	59.65		59.18		47.84*		52.78		61.30		52.98		48.03*		51.21*		
Widowed¶	7.97		12.27		9.13		10.09		12.85		18.91*		23.59*		27.05*		
Never married	32.38		28.27		43.04		37.13		25.86		28.11		28.38		21.74		
Smoking*																	
Never smoker	50.19		36.41*		35.44*		31.15*		58.59		59.82		58.72		31.55*		
Ex-smoker	20.33		15.25		13.23		17.17		16.81		7.78*		9.43*		12.30		
Current smoker	29.48		48.34		51.33		51.67		24.60		32.40*		31.86*		56.14*		
Less than median height (%)	34.99		50.30*		58.81*		52.89*		37.99		53.7*		51.37*		40.15		
Age (years) (range: 18–50)	34.06	0.37	32.08	0.81	33.64	0.89	33.58	0.31	34.87	0.42	32.87	0.76	33.59	0.88	34.62	0.35	
Income (PIR)††	3.31	0.09	1.62*	0.11	1.35*	0.08	1.18*	0.14	3.15	0.10	1.51	0.12	1.51	0.19	1.26	0.13	

*Pearson's χ^2 test of independence with Rao and Scott correction, significant at $P < 0.05^{(92)}$. Overall F test was used to test differences in age and income across levels of food security; significant differences were tested at $P < 0.05$.
 †Values are based on subjects aged 18–50 years in the National Health and Nutrition Examination Survey (NHANES) 1999–2002 with non-missing data for age, bioelectrical impedance analysis, body weight, food security status, gender and height. NHANES 1999–2002 design corrections and four-year MEC (mobile examination centre) sampling weights were applied. Percentages should be totalled within columns. Within-column values may not add up to 100% because of rounding.
 ‡Non-Hispanic White includes other white ethnicity.
 §Includes Mexican-Americans and other Hispanics.
 ||Married includes living with a partner.
 ¶Widowed includes divorced or separated.
 ††PIR, poverty income ratio, is income expressed as a ratio of the federal poverty threshold provided by the Bureau of Census.
 ##Standard error corrected using Taylor's linearized method to account for complex survey design.

Table 2 Anthropometric characteristics of the study sample categorized by gender and adult food security status

Measure	Food security status†							
	Fully food-secure‡		Marginal food security		Food-insecure without hunger		Food-insecure with hunger	
	Mean	SE§	Mean	SE§	Mean	SE§	Mean	SE§
Men	<i>(n 1573)</i>		<i>(n 187)</i>		<i>(n 234)</i>		<i>(n 123)</i>	
Weight (kg)¶	84.78	0.28	82.53	1.26	76.33*	1.71	75.47*	1.42
Percentage body fat	24.91	0.18	26.01	0.70	22.82*	0.92	22.23*	0.75
BMI (kg/m ²)	26.98	0.21	27.43	0.72	25.51*	0.74	25.55*	0.66
Height (cm)¶	177.08	0.27	176.46	0.73	175.05*	0.94	175.25*	0.93
Women	<i>(n 1432)</i>		<i>(n 204)</i>		<i>(n 175)</i>		<i>(n 98)</i>	
Weight (kg)	72.75	0.69	74.84	1.38	72.72	2.19	73.81	2.40
Percentage body fat	35.94	0.27	35.66	0.63	35.66	0.93	35.00	1.03
BMI (kg/m ²)	27.24	0.22	28.13	0.58	27.23	0.78	26.94	0.98
Height (cm)¶	163.54	0.15	162.26*	0.50	163.00	0.59	163.66	0.76

*Significantly different from the fully food-secure category, $P < 0.05$. The t statistic on each β coefficient was used to determine significance.
 †Values are based on subjects aged 18–50 years in the National Health and Nutrition Examination Survey (NHANES) 1999–2002 with non-missing data for age, bioelectrical impedance analysis, body weight, food security status, gender and height. NHANES 1999–2002 design corrections were applied and all estimates were weighted using NHANES four-year MEC (mobile examination centre) sampling weights.
 ‡Food-secure men and women were the referent groups.
 §Standard error corrected using Taylor's linearized method to account for complex survey design.
 ¶Values were adjusted using gender-stratified multiple regression models which controlled for age, education, ethnicity, income and smoking.

Table 3 Percentage body fat (%BF) and BMI categorized by adult food security status and height (HT)

Measure†	Food security status‡							
	Fully food-secure§		Marginal food security		Food-insecure without hunger		Food-insecure with hunger	
	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Men	<i>(n 669)</i>		<i>(n 108)</i>		<i>(n 155)</i>		<i>(n 79)</i>	
Below median HT (<174.7 cm)								
%BF	23.78	0.26	24.36	1.07	21.60*	1.18	21.57*	1.22
BMI (kg/m ²)	26.98	0.21	27.43	0.72	25.51*	0.74	25.55*	0.66
Median HT or taller (\geq 174.7 cm)	<i>(n 904)</i>		<i>(n 79)</i>		<i>(n 79)</i>		<i>(n 44)</i>	
%BF	25.53	0.20	26.92	1.20	23.55*	1.24	22.01*	1.23
BMI (kg/m ²)	27.18	0.13	27.53	0.72	25.83*	0.69	24.08*	0.93
Women	<i>(n 646)</i>		<i>(n 117)</i>		<i>(n 109)</i>		<i>(n 47)</i>	
Below median HT (<161.7 cm)								
%BF	35.76	0.43	35.95	0.95	36.15	1.05	33.94	1.60
BMI (kg/m ²)	27.72	0.36	29.60*	0.97	28.03	0.93	28.59	1.56
Median HT or taller (\geq 161.7 cm)	<i>(n 786)</i>		<i>(n 87)</i>		<i>(n 66)</i>		<i>(n 51)</i>	
%BF	36.06	0.29	35.33	0.98	35.16	1.52	35.36	1.00
BMI (kg/m ²)	26.97	0.26	26.69	0.84	26.70	1.40	25.73	0.96

*Significantly different from the fully food-secure category, $P < 0.05$. The t statistic on each β coefficient was used to determine significance.
 †Mean values were adjusted using gender-stratified multiple regression models which controlled for age, education, ethnicity, income and smoking. National Health and Nutrition Examination Survey (NHANES) 1999–2002 design corrections were applied and all estimates were weighted using NHANES four-year MEC (mobile examination centre) sampling weights.
 ‡Values are based on subjects aged 18–50 years in the NHANES 1999–2002 with non-missing data for age, bioelectrical impedance analysis, BIA, body weight, food security status, gender and height.
 §Food-secure men and women were the referent group.
 ||Standard error corrected using Taylor's linearized method.

All-cause mortality risk was double for men who were below 165 cm in HT compared with taller men⁽³⁸⁾. A significant association between short HT and higher incidence of prostate cancer has been reported⁽³⁹⁾. Previous studies have shown food-insecure individuals to be at greater risk of developing many of these chronic diseases^(4,40,41). Our finding that FI was associated with lower HT underscores the public health importance of nutrition programmes that target individuals during the critical times of growth. The positive influence on infant length and well-being through participation in federal food assistance programmes has been reported^(42,43).

%BF and BMI showed similar trends across food security levels in men but not in women. Physiological adaptation in women such as leptin-mediated maintenance of critical fat mass for reproduction may contribute to obscure differences in %BF across food security levels⁽⁴⁴⁾. The levels of FI observed in this population may not indicate energy shortage among women⁽⁴⁵⁾. In addition, differences in %BF among women might have been obscured by the already elevated %BF of the referent group, fully food-secure women, in the present study.

The strengths of our study lie in the fact that we assessed two indicators of adiposity, %BF and BMI, to

study their associations with FI. Another strength is that the study accounted for important covariates including smoking status, which is common among food-insecure persons and influences their dietary intake and composition^(46,47) and body weight^(48,49). Available literature indicates that, unlike the present study, only a few controlled for smoking in the study of the associations between FI and BMI⁽⁵⁰⁾. However, there is significant inverse association between smoking and body weight⁽⁴⁹⁾. In the present study, food security status information covered a reference period of 12 months to improve sensitivity and to provide a more reliable assessment. Another important strength is that the study comprised a large sample of persons in the USA and that the conduct of the study was carefully standardized.

In the present study, we observed a significant interaction between food security status and HT in the association between FI and BMI. This observation indicates that the trend in the association between FI and BMI was different at different levels of HT. This observation further underscores the fact that HT should be considered when examining the association between FI and BMI as an index of obesity.

A limitation of the study is that the relationships between FI and %BF and BMI were based on cross-sectional data which do not permit inferences related to causality^(5,11). BIA is a well-recognized method for %BF assessment^(20–22). However, assessment of %BF using BIA may not be appropriate for individuals who have extremely low or extremely high BMI because %BF does not increase linearly with increasing body weight^(51,52). Even though our sample size is large, it must be noted that the present study is based on a subsample of the subjects in the larger NHANES 1999–2002. Thus the finding of the study may not be representative of the larger NHANES sample.

The present study shows that FI is associated with lower %BF, BMI and HT in men, and marginal food security is associated with shorter HT in women. A significantly positive association of BMI with marginal food security was found among women who were below the median HT. These observations highlight the need for more vigorous public health efforts to alleviate the effects of FI and to improve food security in this population. Longitudinal studies, which should include repeated measures of FI, HT, weight and adiposity indicators across the life cycle, are needed to further elucidate the associations between FI and %BF, BMI and HT.

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