Low-income Supplemental Nutrition Assistance Program participation is related to adiposity and metabolic risk factors[1–3]

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ABSTRACT

Background: The Supplemental Nutrition Assistance Program (SNAP) is the largest federal nutrition assistance program. In recent years, SNAP participation rates increased during times of economic hardship.

Objective: We examined whether household SNAP participation was associated with adiposity and metabolic risk factors in a representative sample of low-income US adults.

Design: A cross-sectional analysis was performed with the use of data from the 2003–2006 National Health and Nutrition Examination Surveys. The study population was restricted to nonelderly adults whose household incomes fell to or <130% of the federal poverty level. Multinomial logistic and Poisson regression models were fit to examine the associations between SNAP participation and BMI, waist circumference, and metabolic risk factors among 2250 low-income adults.

Results: In the previous 12 mo, 32.8% of adults received household SNAP benefits. SNAP participation was positively associated with obesity [prevalence ratio (PR): 1.58; 95% CI: 1.08, 2.31], waist circumference in men (PR for top compared with bottom quartile: 2.04; 95% CI: 1.15, 3.62; $P = 0.02$), and waist circumference in women (PR: 2.95; 95% CI: 1.51, 5.77; $P = 0.003$; P-interaction with sex = 0.11), independent of sociodemographic characteristics. SNAP participation was also related to elevated triglycerides (PR: 1.71; 95% CI: 1.33, 2.20), lower HDL cholesterol (PR: 1.23; 95% CI: 1.08, 1.41), elevated fasting glucose ($\geq$110 mg/dL; PR: 1.63; 95% CI: 1.05, 2.52), and metabolic syndrome (PR: 1.49; 95% CI: 1.13, 1.95). Associations with triglycerides and HDL cholesterol persisted after adjustment for BMI.

Conclusion: Household SNAP participation was positively associated with BMI, waist circumference, and metabolic risk factors among low-income adults. These associations may be mediated by dietary intake and warrant further investigation. *Am J Clin Nutr* 2012;95:17–24.

INTRODUCTION

The federal SNAP[4], formerly the FSP, aims to alleviate food insecurity and improve the dietary intake of participants through benefits to purchase household food items. SNAP eligibility is determined by having a household income at or below 130% of the FPL and <$2000 in countable assets (1). In recent years, participation in SNAP has increased dramatically because more households have fallen into poverty (2). In 2010, $68 billion was spent on SNAP, with 40.3 million persons receiving benefits (2).

Between July 2010 and July 2011, there was a 10.4% increase in SNAP participation among US households (3).

A 2007 USDA report reviewed several previous studies exploring the relation between SNAP participation and obesity (4). Among children, there appeared to be no association between FSP participation and overweight or obesity; these findings were relatively consistent across data sets and analytic methods. Among adults, longitudinal studies using fixed-effect (5, 6), discrete factor (7), and bivariate probit models (8) suggested a positive relation between FSP participation and BMI and obesity in nonelderly adult women, although not in men. However, the magnitude of the associations among women varied widely depending on the data set and the analytic methods used, and many studies used data collected before 2000. Longitudinal studies using dynamic models found no association between FSP participation and BMI (9, 10). In one of these studies, food insecurity was positively related to BMI among elderly nonparticipants, but was not related to BMI among elderly FSP participants (10). Studies using instrumental variable models have also yielded inconsistent results (5, 11), likely owing to the difficulty in selecting a valid instrument (12).

If a causal relation exists between SNAP participation and BMI, the mechanisms are potentially complicated. The first hypothesized mechanism is that the association may be mediated by dietary behaviors, particularly consumption of inexpensive, energy-dense foods of minimal nutritional value (13–15). Wilde et al (16) observed that FSP participants consumed more meats, added sugars, and total fats as a result of program participation. Over time, these foods may contribute to higher total energy

[4] Abbreviations used: ADA, American Diabetes Association; ATP III, Adult Treatment Panel III; FAS, fasting subsample; FPL, federal poverty level; FSP, Food Stamp Program; MEC, mobile examination center; PR, prevalence ratio; SNAP, Supplemental Nutrition Assistance Program; WIC, the Special Supplemental Nutrition Program for Women, Infants and Children.

intake among program participants (4). The results have been inconclusive among other studies examining SNAP participation and dietary intake. The second hypothesized mechanism relates to the monthly distribution of SNAP benefits, and the availability of benefits affecting food purchasing and dietary behaviors throughout the month (17). Participants may overcompensate for energy intake during the weeks when SNAP benefits are available and restrict food intake when SNAP benefits are depleted (17). This cyclic behavior may lead to weight gain over time (18). However, more research is needed to determine how the frequency of benefits distribution affects dietary intake and weight management among low-income SNAP participants.

Obesity is a strong risk factor for several health conditions, including hypertension, hypercholesterolemia, and hyperglycemia. Collectively, these conditions, known as the metabolic syndrome, increase the risk of coronary heart disease, stroke, and diabetes mellitus (19). Whereas the associations between SNAP participation and BMI have been examined in previous studies, little is known about the relations between SNAP participation and other adiposity measures or metabolic risk factors.

Using a nationally representative sample of nonelderly low-income adults, we examined the associations of SNAP participation with BMI and waist circumference, independent of sociodemographic characteristics and household food insecurity. We also examined whether SNAP participants and nonparticipants had different prevalences of metabolic risk factors after sociodemographic characteristics, household food insecurity, and BMI were accounted for and whether the associations differed between men and women.

SUBJECTS AND METHODS

Study population

NHANES is an ongoing, multistage cross-sectional survey administered by the National Center for Health Statistics. NHANES is designed to be representative of the civilian, non-institutionalized US population and collects information on general health status, nutritional intake, health-related behaviors, and physiologic measurements from an in-home questionnaire and a physical examination in the Mobile Examination Centers. Laboratory analysis of blood and urine samples are also conducted on a subset of NHANES participants.

This analysis combined data from the 2003–2004 and 2005–2006 surveys to ensure a sufficient representation of SNAP participants. The analytic sample was restricted to households whose incomes fell at or below 130% of the federal poverty level to include only individuals who may be eligible to receive SNAP benefits. We further restricted our analysis to adults aged 18–65 y and excluded pregnant women to avoid misclassification of our outcome measures. The sample consisted of 2250 adults; however, the sample size varied across analytic models as certain outcomes were only collected among a subset of study participants.

Outcomes

Outcome variables for analyses included BMI, waist circumference, plasma fasting triglycerides, HDL cholesterol, blood pressure, fasting glucose, and the metabolic syndrome.

Adiposity measurements

Height (in m) and weight (in kg) were measured by trained personnel with a Toledo weight scale and stadiometer (20). BMI was calculated as weight (kg) divided by the square of height (m) and further collapsed into standard weight categories: underweight (BMI <18.5), normal weight (BMI 18.5–24.9), overweight (BMI 25.0–29.9), and obese (BMI ≥30.0) (21). Waist circumference (cm) was measured by trained personnel at the upper lateral border of the right ilium (20). For analysis as an adiposity outcome, waist circumference was categorized by sex-specific quartiles. For men, quartiles were defined at 82.5, 93.25, and 103.8 cm. For women, quartiles were defined at 81.8, 93.0, and 105.75 cm.

Metabolic risk factors

The National Cholesterol Education Program ATP III guidelines were used to define the cutoffs for the metabolic risk factors (elevated waist circumference, elevated triglycerides, lower HDL cholesterol, and elevated blood pressure) (22). Elevated waist circumference was defined as ≥102 cm for men and ≥88 cm for women. Plasma triglycerides (mg/dL) were measured in the morning from persons who had fasted for ≥8.5 h Details of the laboratory procedures are described elsewhere (23). Elevated triglycerides were defined as ≥150 mg/dL. Serum HDL cholesterol (mg/dL) was measured from blood specimens obtained from the mobile examination center laboratory. Details of specimen collection and processing are described elsewhere (24). Lower HDL cholesterol was defined as <40 mg/dL for men and <50 mg/dL for women. For blood pressure, 4 consecutive systolic and diastolic blood pressure readings (mm Hg) were taken in the mobile examination center by certified physical examiners. The average of the first 3 readings was obtained and used for analysis. For individuals with <3 readings, the average of the first and/or second readings was used for analysis. Individuals were excluded if they had partial or missing blood pressure status, or reported consuming food, alcohol, cigarettes, or coffee within the past 30 min. Elevated blood pressure was defined as ≥130/85 mm Hg. Fasting plasma glucose (mg/dL) was measured in the morning from persons who had fasted for ≥9 h Details of the laboratory procedures are described elsewhere (25). Because there has been disagreement about the optimal threshold for fasting glucose (26), elevated glucose was first defined as ≥100 mg/dL on the basis of the current ADA cutoff for impaired fasting glucose (27) and second as ≥110 mg/dL on the basis of the WHO cutoff for impaired fasting glucose (28). The ADA cutoff was used as a lower boundary for identifying individuals with impaired fasting glucose; the WHO cutoff was used as a more "sensitive" indicator of impaired fasting glucose and to maintain consistency with the classification of metabolic syndrome.

Metabolic syndrome

Per the ATP III guidelines, the metabolic syndrome was defined as the presence of ≥3 of the following conditions: elevated waist circumference, triglycerides, blood pressure, and fasting glucose (≥110 mg/dL) and lower HDL cholesterol (22).

SNAP participation

SNAP participation was defined as answering "yes" to the survey question, "In the last 12 months, were you or any members

of your household authorized to receive Food Stamps?" SNAP participation was measured at the household level.

Sociodemographic characteristics

Covariates for multivariate regression analyses included age, sex, race (non-Hispanic white, Hispanic, African American, or other/multiple races), place of birth (United States–born or foreign-born), education level (<12 y, high school graduate or equivalent, some college or Associate's degree, or Bachelor's degree or higher), marital status (single; married or living with partner; widowed or separated or divorced), household size, smoking status (never smoker, former smoker, or current smoker), health insurance status (private insurance, public insurance, or no insurance), poverty income ratio (0–25% FPL, 25.1–50% FPL, 50.1–75% FPL, 75.1–100% FPL, or 100.1–130% FPL), household participation in WIC in the past 12 mo, and household food security (full food security, marginal food security, low food security, or very low food security). Household food security was assessed by using the 18-item US Food Security Survey Module (29).

Statistical analysis

Complex survey weights were used to account for different sampling probabilities and participation rates for the various components of NHANES and to obtain effect estimates and SEs representative of the US population. Weights from the MEC and the FAS were recalculated to reflect the probability of being sampled in the 4-y period (30). MEC weights were used for all models fit for measures of adiposity, HDL cholesterol, and blood pressure. Models for triglycerides, glucose, and the metabolic syndrome used FAS weights. All models were restricted to our study population of interest. SEs were estimated by using robust sandwich variances.

We first compared sociodemographic characteristics and food insecurity between SNAP participants and nonparticipants by using chi-square tests. Next, we evaluated associations between SNAP participation and measures of adiposity by fitting multinomial logistic regression models for the outcomes of BMI categories and waist circumference quartiles. Individuals with a normal BMI (18.5–24.9) and in the first quartile of waist circumference were used as the reference groups. The first model adjusted for age. The multivariate model adjusted for age, sex, race, place of birth, education level, marital status, household size, smoking status, health insurance status, poverty income ratio, WIC participation, and household food security. We also conducted trend tests by running multivariate logistic regression models for the outcome of SNAP participation by using BMI categories and waist circumference quartiles as ordinal variables.

To examine the cross-sectional associations between SNAP participation and metabolic risk factors, Poisson regression models were used to estimate PRs for SNAP participation and the different outcomes. Previous studies have suggested that Poisson regression models with robust variance estimation provide PRs that are consistent, more interpretable, and more conservative than the prevalence ORs estimated from binomial regression in cross-sectional studies (31–33). The first model adjusted for age. The multivariate model included all sociodemographic characteristics and household food security as covariates. The third

model added BMI categories to assess the relations between SNAP participation and metabolic risk factors independent of the effects from BMI; a missing indicator was used to account for adults with missing BMI data ($n = 97$).

We also examined whether the associations between SNAP and measures of adiposity or metabolic risk factors were modified by sex. Regression models were fit for each outcome separately for men and women. All statistical tests were 2-sided, and significance was considered at $P < 0.05$. Statistical analyses were performed by using Stata/IC 11.1 (StataCorp LP).

RESULTS

Of the 2250 adults in the study population, 32.8% reported participation in SNAP within the past 12 mo. Compared with nonparticipants, SNAP participants were more likely to be female, to have been born in the United States, to be African American, to have <12 y of formal education, to be living in a larger household, and to be insured with public types of health insurance (eg, Medicaid, state-sponsored health plan, or other government insurance) (**Table 1**). Household food insecurity was prevalent among SNAP participants; 24.6% experienced low food security and 21.3% experienced very low food security in the past year.

Among SNAP participants, 23.7% were overweight and 44.0% were obese (**Table 2**). After adjustment for sociodemographic characteristics, the odds of obesity was 58% higher among SNAP participants than among nonparticipants (OR: 1.58; 95% CI: 1.08, 2.31; P-trend = 0.006). There was no significant effect modification by gender of the association between SNAP participation and BMI/obesity. SNAP participation was also positively associated with waist circumference in men and women. For men, SNAP participants had twice the odds of being in the top quartile of waist circumference compared with male nonparticipants (OR = 2.04, 95% CI: 1.15, 3.62; P-trend = 0.06). For women, SNAP participants had nearly 3 times the odds of being in the top quartile of waist circumference compared with female nonparticipants (OR = 2.95, 95% CI: 1.51, 5.77; P-trend = 0.001). Despite the difference in the associational measures, the interaction was not statistically significant (P-interaction with sex = 0.11).

We next examined whether SNAP participation was associated with metabolic risk factors (**Table 3**). Among SNAP participants, the most prevalent risk factors were elevated waist circumference, elevated fasting triglycerides, and lower HDL cholesterol. After adjustment for sociodemographic characteristics and household food security, SNAP participation was associated with elevated triglycerides (PR: 1.71; 95% CI: 1.33, 2.20) and lower HDL cholesterol (PR: 1.23; 95% CI: 1.08, 1.41). After the effect of BMI was accounted for, the associations between SNAP participation and elevated triglycerides and lower HDL cholesterol remained significant. Although the association with elevated triglycerides appeared stronger for women (PR: 1.97; 95% CI: 1.29, 3.02) than for men (PR: 1.45; 95% CI: 0.99, 2.11; $P = 0.06$) (*see* Tables S1 and S2 under "Supplemental data" in the online issue), the interaction was not statistically significant ($P = 0.26$).

SNAP participation was not significantly associated with elevated fasting glucose on the basis of the ADA cutoff of 100 mg/dL; however, it was associated with the WHO cutoff of 110 mg/dL (PR: 1.63; 95% CI: 1.05, 2.52). This association was attenuated

TABLE 1
Sociodemographic characteristics of adults at or below 130% of the federal poverty level[1]

	SNAP participants (n = 723)	SNAP nonparticipants (n = 1527)
Age (y)	36.3 ± 0.7[2]	36.9 ± 0.8
Female [n (%)]	402 (59.1)	776 (51.0)
Born in the United States [n (%)]	598 (83.7)	957 (70.8)
Race [n (%)]		
Non-Hispanic white	222 (47.6)	467 (52.4)
African American	297 (30.0)	350 (13.7)
Hispanic/Latino	183 (19.0)	626 (26.4)
Other or multiple ethnicities	21 (3.5)	84 (7.4)
Education level [n (%)]		
<12 y	351 (43.3)	603 (31.8)
High school graduate or equivalent	191 (29.0)	420 (29.0)
Some college or AA degree	154 (24.8)	406 (31.0)
College graduate or above	17 (2.9)	78 (8.2)
Marital status [n (%)]		
Single	268 (29.7)	625 (32.6)
Married or living with partner	290 (43.9)	656 (49.2)
Widowed, separated, or divorced	165 (26.4)	245 (18.2)
Household size (n)	3.8 ± 0.1	3.5 ± 0.1
Smoking status [n (%)]		
Never smoker	259 (34.7)	743 (49.4)
Former smoker	94 (15.7)	182 (14.1)
Current smoker	355 (49.6)	562 (36.5)
Health insurance status [n (%)]		
Not insured	240 (31.7)	722 (47.1)
Insured with public insurance	404 (57.1)	343 (22.0)
Insured with private insurance	75 (11.2)	441 (31.9)
Poverty income ratio [n (%)]		
0–25% of FPL	93 (12.1)	215 (12.6)
25.1–50% of FPL	128 (15.6)	160 (9.7)
50.1–75% of FPL	177 (24.6)	270 (16.0)
75.1–100% of FPL	185 (27.4)	397 (24.5)
100.1–130% of FPL	140 (20.2)	485 (37.1)
Household WIC participation [n (%)]	244 (32.2)	263 (15.2)
Household food security [n (%)]		
Full food security	272 (37.4)	848 (58.4)
Marginal food security	117 (16.6)	223 (12.9)
Low food security	188 (24.6)	319 (19.1)
Very low food security	145 (21.3)	136 (9.6)

[1] All differences in sociodemographic characteristics between SNAP participants and SNAP nonparticipants, except for age, were statistically significant, $P < 0.05$ (chi-square tests). AA, Associates of Arts; FPL, federal poverty level; SNAP, Supplemental Nutrition Assistance Program; WIC, Special Supplemental Nutrition Program for Women, Infants and Children.
[2] Mean ± SE (all such values).

after adjustment for BMI (PR: 1.49; 95% CI: 0.90, 2.47; $P = 0.12$). The association with elevated fasting glucose ($\geq$110 mg/dL) was stronger for women (PR: 2.03; 95% CI: 1.07, 3.88) than for men (PR: 1.30; 95% CI: 0.66, 2.56); however, the interaction was not significant ($P = 0.33$).

Approximately 33.6% of SNAP participants met the diagnostic criteria for the metabolic syndrome. Consistent with the WHO and ATP III guidelines, the fasting glucose cutoff of 110 mg/dL was used to define elevated fasting glucose as one criterion for the metabolic syndrome. SNAP participation was positively associated with the metabolic syndrome (PR: 1.49; 95% CI: 1.13, 1.95), although this association was attenuated after adjustment for BMI (PR: 1.32; 95% C:I 0.95, 1.81; $P = 0.09$). No significant effect modification by sex was found between SNAP participation, the metabolic syndrome, or any other metabolic risk factors ($P > 0.20$ for all).

DISCUSSION

In this nationally representative sample of nonelderly, low-income adults, we found that household participation in SNAP was associated with obesity, waist circumference, elevated triglycerides, lower HDL cholesterol, elevated fasting glucose ($\geq$110 mg/dL), and the metabolic syndrome. These associations were independent of sociodemographic factors and household food insecurity.

Our findings corroborate results from previous studies that have observed positive relations between SNAP participation and BMI (5, 6, 14, 34–36) and extend the association to waist circumference. When men and women were analyzed separately, our results suggest that the association with waist circumference quartiles was stronger among low-income women, although a positive association was also found among low-income men. SNAP participation

TABLE 2
Participation in SNAP and associations with adiposity among adults at or below 130% of the federal poverty level[1]

	SNAP participants	SNAP nonparticipants	Age-adjusted[2]		Multivariate-adjusted[2,3]	
			OR	95% CI	OR	95% CI
	n (%)	*n (%)*				
BMI						
Normal, 18.5–24.9 kg/m^2	221 (30.1)	539 (36.9)	Ref		Ref	
Underweight, <18.5 kg/m^2	15 (2.3)	43 (3.5)	0.93	0.48, 1.79	0.58	0.26, 1.28
Overweight, 25.0–29.9 kg/m^2	169 (23.7)	457 (33.1)	0.90	0.67, 1.19	0.81	0.59, 1.10
Obese, ≥30 kg/m^2	295 (44.0)	414 (26.6)	2.15	1.63, 2.85	1.58	1.08, 2.31
P-trend				<0.001		0.006
Waist circumference, men only						
Quartile 1, <82.5 cm	71 (15.1)	178 (21.8)	Ref		Ref	
Quartile 2, 82.5 to <93.25 cm	76 (27.1)	178 (24.9)	1.69	0.97, 2.92	1.87	0.93, 3.74
Quartile 3, 93.25 to <103.8 cm	73 (26.0)	177 (28.5)	1.49	0.81, 2.74	1.79	0.87, 3.68
Quartile 4, ≥103.8 cm	85 (31.9)	168 (24.8)	2.17	1.29, 3.64	2.04	1.15, 3.62
P-trend				0.02		0.06
Waist circumference, women only						
Quartile 1, <81.8 cm	66 (16.8)	203 (26.4)	Ref		Ref	
Quartile 2, 81.8 to <93.0 cm	83 (23.4)	192 (30.9)	1.16	0.64, 2.08	1.42	0.70, 2.89
Quartile 3, 93.0 to <105.75 cm	95 (22.5)	184 (24.6)	1.44	0.87, 2.38	1.33	0.66, 2.68
Quartile 4, ≥105.75 cm	131 (37.3)	143 (18.1)	3.68	2.13, 6.37	2.95	1.51, 5.77
P-trend				<0.001		0.001

[1] Ref, reference; SNAP, Supplemental Nutrition Assistance Program.

[2] ORs and 95% CIs were estimated from multinomial logistic regression models with normal BMI and quartile 1 of waist circumference as reference groups.

[3] Adjusted for age; sex; race; place of birth; education level; marital status; household size; health insurance status; poverty income ratio; smoking status; Special Supplemental Nutrition Program for Women, Infants and Children participation; and household food security. Sex was excluded as a covariate in waist circumference models specific to men and women.

was also associated with the prevalence of elevated triglycerides and lower HDL cholesterol and marginally associated with the metabolic syndrome, independent of the effects of BMI. It was previously suggested that associations from cross-sectional studies may be partly explained by reverse causation, ie, overweight or obese individuals are more likely to seek out SNAP benefits because of a desire to consume more food. Because we observed positive associations between SNAP participation and some metabolic risk factors, even after BMI was controlled for, it seems unlikely that reverse causation completely accounts for these associations. These findings may have important public health implications, because previous studies have found that adults with risk factors of the metabolic syndrome are at an increased risk of cardiovascular disease (37) and all-cause mortality (37, 38).

The associations with adiposity and metabolic risk factors may be mediated by dietary behaviors. Studies that examined whether SNAP participants have higher total energy intakes than nonparticipants had mixed results (4, 39–43). A report by Ver Ploeg and Ralston (4) observed that female SNAP participants consumed more calories than did female nonparticipants, but male SNAP participants consumed fewer calories than did male nonparticipants. Aside from total energy, previous studies have observed that SNAP participants consumed significantly more meat products, added sugars, regular soft drinks, total fat, and total energy than did nonparticipants (16, 34, 44). Several of these dietary components have been associated with obesity (45, 46) and the metabolic syndrome among higher-income populations (47–51).

Differential patterns of eating behaviors corresponding to the monthly distribution of SNAP benefits have led researchers to coin the term "the food stamp cycle." Participants may overcompensate for energy intake during the weeks when SNAP benefits are available and restrict food intake when SNAP benefits are depleted (17). In a 2000 report, mean food expenditure per person per household peaked and declined after the first 3 d of receiving food stamp benefits (52). Throughout the month, individual energy intakes were consistently lower than the Recommended Dietary Allowance for total calories. These averages may have masked differences by household or food type, because it was also observed that the purchase and consumption of specific food items varied depending on the week of benefit availability. Whereas this report suggests that the food stamp cycle may not be a strong contributor to obesity among SNAP participants, more research is needed to confirm the results of this report and to determine the extent that the food stamp cycle may contribute to obesity among certain subgroups of SNAP participants.

A considerable strength of our study was the use of a representative sample of nonelderly, low-income adults. Because anthropometric measures were collected by trained personnel rather than reported by the participants, we were able to minimize potential misclassification of our adiposity outcomes. Furthermore, the NHANES response rates for the 2003–2004 and 2005–2006 surveys were 76% and 77%, respectively (53, 54). These response rates are considerably higher than other state-wide or national health surveys and may help to ensure a representative sample with minimal selection bias.

The key limitation of the current study was its cross-sectional nature, which makes it difficult to infer the temporality of the variables. For example, experiences of food insecurity and SNAP participation were each measured within the previous 12 mo. Because food insecurity levels can change after acquiring SNAP

TABLE 3
Participation in the SNAP and associations with metabolic risk factors among adults at or below 130% of the federal poverty level[1]

	SNAP participants	SNAP nonparticipants	Age-adjusted[2]		Multivariate-adjusted[2,3]		Multivariate- + BMI-adjusted[2,3]	
			PR	95% CI	PR	95% CI	PR	95% CI
	n (%)	*n (%)*						
Waist circumference								
Normal, <102 cm for M; <88 cm for F	323 (44.8)	814 (56.6)	Ref		Ref		Ref	
Elevated, ≥102 cm for M; ≥88 cm for F	357 (55.2)	609 (43.4)	1.29	1.15, 1.45	1.14	0.99, 1.31	0.99	0.88, 1.10
Triglycerides								
Normal, <150 mg/dL	200 (62.8)	480 (72.4)	Ref		Ref		Ref	
Elevated, ≥150 mg/dL	111 (37.3)	171 (27.6)	1.45	1.13, 1.84	1.71	1.33, 2.20	1.67	1.28, 2.18
HDL								
Normal, ≥40 mg/dL for M; ≥50 mg/dL for F	426 (59.4)	962 (67.7)	Ref		Ref		Ref	
Lower, <40 mg/dL for M; <50 mg/dL for F	256 (40.6)	431 (32.3)	1.26	1.13, 1.40	1.23	1.08, 1.41	1.16	1.00, 1.36
Blood pressure[4]								
Normal, <130/85 mm Hg	298 (77.2)	672 (75.3)	Ref		Ref		Ref	
Elevated, ≥130/85 mm Hg	89 (22.8)	195 (24.7)	0.90	0.73, 1.12	0.93	0.73, 1.19	0.90	0.68, 1.18
Fasting glucose, ADA cutoff								
Normal, <100 mg/dL	204 (67.1)	433 (65.8)	Ref		Ref		Ref	
Elevated, ≥100 mg/dL	112 (32.9)	225 (34.2)	1.00	0.80, 1.24	1.18	0.90, 1.55	1.08	0.81, 1.45
Fasting glucose, WHO cutoff								
Normal, <110 mg/dL	262 (88.4)	568 (84.5)	Ref		Ref		Ref	
Elevated, ≥110 mg/dL	54 (11.6)	90 (15.5)	1.39	0.96, 2.00	1.63	1.05, 2.52	1.49	0.90, 2.47
Metabolic syndrome								
<3 of above conditions present	265 (73.8)	659 (81.3)	Ref		Ref		Ref	
≥3 of above conditions present	77 (26.2)	123 (18.7)	1.51	1.09, 2.10	1.49	1.13, 1.95	1.32	0.95, 1.81

[1] ADA, American Diabetes Association; F, females; M, males; PR, prevalence ratio; Ref, reference; SNAP, Supplemental Nutrition Assistance Program.
[2] PRs and 95% CIs were estimated from Poisson regression models,
[3] Adjusted for age (in 5-y categories); sex; race; place of birth; education level; marital status; household size; health insurance status; poverty income ratio; smoking status; Special Supplemental Nutrition Program for Women, Infants and Children participation; and household food security.
[4] Systolic and diastolic blood pressure calculated as the average of the first 3 readings.

benefits (55), it is difficult to determine whether food insecurity is reported before or after SNAP participation occurred. For this reason, we ran multivariate models, including and excluding household food insecurity as a covariate. The associations did not change significantly with household food insecurity in the model. Thus, we presented associations that adjusted for household food insecurity, because bivariate analyses showed that SNAP participants were more likely to report low food security or very low food security when compared with nonparticipants. Second, some outcome variables had small sample sizes, which may have limited our statistical power to detect associations. Outcomes such as plasma glucose and serum triglycerides were only collected from a subsample of adults who had completed an overnight fast. However, significant associations were observed with these outcomes despite the smaller sample sizes. Furthermore, the NHANES sampling weights adjust for nonresponse specifically of the MEC or the FAS; however, they do not adjust for missing data for our specific outcomes of interest (eg, BMI and blood pressure). For this missingness to introduce bias, missing data would have to be related to both SNAP participation and with metabolic risk factors. In our study, SNAP participation was not related to missingness for any of our outcome variables. Our results were generally robust in various sensitivity analyses. There was also the potential for unmeasured confounding by other lifestyle factors, such as physical activity—a known risk factor for obesity and lower HDL cholesterol—or factors related to SNAP participation, such as length of participation. Although physical activity questionnaires were administered as part of the

NHANES 2003–2006, 41% (933/2250) of our study population were missing these variables.

Misclassification of SNAP participation may also exist in our study. SNAP participation is measured at the household level, and we assumed that individuals whose households participate in SNAP share the benefits. Whereas this would generally hold for most household types (eg, households with children, married head households), single persons living together may not always share food costs or consumption and may be incorrectly classified as receiving SNAP. Recent statistics show that only 2.1% of participating households are multiadult households without children, elderly, or disabled persons (56). The prevalence of SNAP participation as estimated from NHANES is lower than the national estimate from the USDA, which suggests that individuals are underreporting SNAP participation. In a previous study, it was hypothesized that men, unmarried individuals, and individuals with higher income are more likely to incorrectly report SNAP participation status, either because of a stigma or lack of knowledge (57). Whereas we have tried to account for the effects of sex, marital status, and poverty income ratio such that, within levels of these variables, the measurement error could be considered nondifferential, it is possible that other differential misclassification of SNAP could bias our results. Future studies might consider correcting for underreporting of SNAP participation by using validation studies.

Researchers have also questioned whether fundamental differences exist between SNAP participants and low-income, eligible nonparticipants that are not captured in large health studies.

This has been termed a "selection bias," where SNAP participants who self-select into public assistance programs possess characteristics that are often unmeasured by national studies. In one study that attempted to account for selection bias, Baum (5) compared estimates from ordinary-least-squares models to those obtained from instrumental variables, fixed-effects, and dynamic models. Significant, positive effects for FSP participation and obesity were observed from ordinary-least-squares models among women; estimates from fixed-effects models were attenuated but still significant. Other results from instrumental variables and dynamic models also supported a positive effect of FSP participation on obesity for women. Findings for men were inconsistent across the models. Baum concluded that, although there was a significant effect of FSP participation on obesity, the effect was small and unlikely to have a significant effect on the national prevalence of obesity. Other studies have also controlled for selection bias using longitudinal models; most studies support a positive association for women, but not for men (4). Although we could not correct for selection bias given the nature of the NHANES data, our results support conclusions from longitudinal studies correcting for selection bias (5–8) and other cross-sectional studies (34, 35). Furthermore, we extend the associations to other adiposity measures and metabolic risk factors in a nationally representative sample of low-income adults.

Recent statistics indicate that the national poverty rate has increased dramatically in the past decade (58). Because SNAP and other food assistance programs act as safety nets for individuals living close to the poverty line, it is important that these programs promote healthy dietary behaviors of their beneficiaries. Whereas longitudinal studies with strong measurement tools are still needed to determine whether these associations are truly causal, programmatic changes to improve the nutritional aspects of the SNAP program may help to improve the health profiles of participants with respect to dietary behaviors.

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