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RESEARCH ARTICLE

SNAP Participation and Diet-Sensitive Cardiometabolic Risk Factors in Adolescents

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Introduction: Previous research suggests participation in the Supplemental Nutrition Assistance Program (SNAP) is associated with poorer adult cardiometabolic health; the extent to which these associations extend to adolescents is unknown. Differences in diet quality, obesity, and cardiometabolic risk factors were examined among SNAP participants, income-eligible nonparticipants, and higher-income adolescents.

Methods: The study population comprised 4,450 adolescents ≤300% federal poverty level from the 2003–2010 National Health and Nutrition Examination Survey. Generalized linear models were used to examine associations between SNAP participation and the Alternate Healthy Eating Index–2010. Linear and logistic regression models were used to examine associations between SNAP participation, obesity, and risk factors comprising the metabolic syndrome. Data were analyzed in 2015.

Results: All surveyed adolescents consumed inadequate amounts of vegetables, fruits, whole grains, and long-chain fatty acids, while exceeding limits for sugary beverages, processed meats, and sodium. Although there were few dietary differences, SNAP participants had 5% lower Alternate Healthy Eating Index–2010 scores versus income-eligible nonparticipants (95% CI=−9%, −1%). SNAP participants also had higher BMI-for-age Z scores (β=0.21, 95% CI=0.01, 0.41), waist circumference Z scores (β=0.21, 95% CI=0.03, 0.39), and waist-to-height ratios (β=0.02, 95% CI=0.00, 0.03) than higher-income nonparticipants. SNAP participation was not associated with most cardiometabolic risk factors; however, SNAP participants did have higher overall cardiometabolic risk Z scores than higher-income nonparticipants (β=0.75, 95% CI=0.02, 1.49) and income-eligible nonparticipants (β=0.55, 95% CI=0.03, 1.08).

Conclusions: Adolescent SNAP participants have higher levels of obesity, and some poorer markers of cardiometabolic health compared with their low-income and higher-income counterparts.
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INTRODUCTION

The Supplemental Nutrition Assistance Program (SNAP) is the largest federal food program that aims to alleviate food insecurity and improve the nutritional outcomes of low-income children and families. In 2014, a total of 46.7 million individuals participated in SNAP: roughly 14% were preschool-age children, 19% were school-age children, and 12% were adolescents.[1]

Several studies have established the protective role that SNAP plays against food insecurity.[2–4] However, the relation between the program and participants' ability to

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eat "a more nutritious diet" is less clear.[5] Unlike other federal food programs, SNAP places little restrictions on foods purchased with program benefits.[6] Other than SNAP-Ed, there are few policies/programs that aim to improve the SNAP participants' nutritional intake. A recent systematic review found few differences among SNAP participants with respect to diet quantity (i.e., total energy, macronutrients) compared to income-eligible nonparticipants and higher-income nonparticipants, but consistent results showing lower diet quality among SNAP participants relative to both nonparticipant groups.[7] These relationships were less evident for children (aged ≤19 years), though children's dietary outcomes have only been examined in four studies to date.[8–11]

Although studies have examined the association between SNAP participation and childhood obesity, the results have been inconsistent.[12–15] A limitation of prior studies is that many employed data from longitudinal studies initiated in the 1960s and 1970s, and thus have not been able to capture the changes in poverty and food insecurity that have occurred during the past decade. Studies using more-recent data are needed to understand how SNAP participation may influence children's weight in the current environment. Aside from obesity, little is known about the relation between SNAP participation and cardiometabolic risk factors among children and adolescents, although these associations have been found in adults.[16] If SNAP participation is associated with children's dietary intake, then its relation to broader cardiometabolic health deserves investigation.

This analysis focused on adolescence because it is a critical period for physical, cognitive, emotional, social, and behavioral development.[17] Furthermore, few studies of SNAP participation have examined this age group, the metabolic syndrome phenotype among adolescents has increased in recent years,[18,19] and adolescent diet quality and weight status track into adulthood,[20,21] influencing lifelong risk of Type 2 diabetes, cancer, and cardiometabolic health.[22–25] In addition, contextual factors like regular family meals and food preparation during adolescence predict higher diet quality in adulthood,[26–28] whereas psychosocial factors like dieting and disordered eating during adolescence persist into early adulthood.[29] Given the significance of the adolescent period, this study examined whether SNAP participation was associated with diet quality, obesity, and cardiometabolic risk factors in a large sample of lower-income adolescents.

METHODS

Study Population

The National Health and Nutrition Examination Survey (NHANES) is an ongoing, multistage survey representative of the civilian, non-institutionalized U.S. population. This analysis combined data from the 2003–2010 surveys to include a sufficient representation of SNAP participants, income-eligible nonparticipants, and higher-income individuals. The analytic sample was restricted to 4,450 adolescents (aged 12–19 years), with household incomes ≤300% of the federal poverty level (FPL). However, there was variation in the sample size across analytic models, as certain outcomes were collected among a subset of study participants.

Measures

Household SNAP participation was defined as the receipt of SNAP benefits within the last 12 months. Adolescents were categorized into three groups: 1,209 SNAP participants with household incomes ≤130% FPL (i.e., SNAP participants), 1,468 nonparticipants with household incomes ≤130% FPL (i.e., income-eligible nonparticipants), and 1,773 nonparticipants with household incomes between 130% and 300% FPL (i.e., higher-income nonparticipants). SNAP participants with household incomes >130% FPL and adolescents with household incomes >300% FPL were excluded.

Dietary intake was assessed using two 24-hour dietary recalls, reported by the adolescent.[30] The first recall was administered in the Mobile Examination Center; the second recall was conducted by telephone. Incomplete dietary recalls (n=798) or recalls with implausible total energy intakes (<500 or >5,000 kcal/day; n=264) were excluded from analysis. Overall diet quality was assessed using the Alternate Healthy Eating Index (AHEI)-2010, a measure developed at the Harvard School of Public Health to be inversely related to chronic disease risk.[31] Data from the U.S. Department of Agriculture Food and Nutrient Database for Dietary Studies and the Food Patterns Equivalents Database were used to calculate the AHEI-2010. Consumption levels were compared with the 2010 Dietary Guidelines for Americans, the 2006 American Heart Association dietary guidelines for foods and food groups, and National Academy of Medicine's Dietary Reference Intakes. The AHEI-2010 was further modified by excluding trans fat, which was unavailable in NHANES, and alcohol, which was considered inappropriate for adolescent diet quality. The overall AHEI-2010 score was rescaled to the original 110 points.

Three anthropometric measures of adiposity were examined: BMI, waist circumference, and waist-to-height ratio (WHtR). Height, weight, and waist circumference were measured by trained personnel.[32] BMI was transformed into Z scores and age- and sex-specific percentiles using the 2000 Centers for Disease Control and Prevention growth charts.[33] Obesity was defined as having a BMI-for-age ≥95th percentile. Waist circumference Z scores were derived from the analytic sample. Elevated waist circumference was defined as having a waist circumference ≥90th percentile, specific to their age, sex, and ethnicity.[34] Elevated WHtR was defined as WHtR >0.5.[35,36]

The following cardiometabolic risk factors were considered: high-density lipoprotein (HDL) cholesterol, systolic blood pressure, fasting triglycerides. and fasting glucose. HDL cholesterol and blood pressure were collected from NHANES participants in the Mobile Examination Center. Average systolic blood pressure was estimated from the first of three readings. Individuals were excluded if they had a partial or missing blood pressure status, or reported consuming alcohol, cigarettes, or coffee within the previous 30 minutes of testing. The International Diabetes Federation criteria were used to define age-appropriate cut offs for adolescents.[37] All cardiometabolic risk factors were converted to Z scores within the analytic sample to facilitate interpretation across risk factors. An overall cardiometabolic risk Z score was created by summing the Z scores; a higher score denoted higher cardiometabolic risk. Per the International Diabetes Federation criteria, metabolic syndrome was defined as waist circumference ≥90th percentile or BMI-for-age ≥95th percentile and the presence of two or more risk factors: elevated triglycerides (≥150 mg/dL); low HDL cholesterol (<40 mg/dL in boys, <50 mg/dL in girls); elevated blood pressure (≥130 mmHg); and elevated fasting glucose (≥100 mg/dL).

Covariates for multivariable models included adolescent's age, sex, race/ethnicity (non-Hispanic white, non-Hispanic black, Hispanic, other or multiple race/ethnicities); household reference (HR) person's birthplace (U.S. or outside of the U.S.), educational attainment (<12 years, high school graduate, any college, college graduate), and marital status (married/living with partner or not partnered); household income, household size, Women, Infants, and Children participation (participant, income-eligible nonparticipant, and higher-income nonparticipant), and household food insecurity (food secure, marginally food secure, and food insecure). Indicators accounted for missing data for HR's birthplace (n=155); HR's education (n=174); HR's marital status (n=331); and household food insecurity (n=597).

Statistical Analysis

Complex survey weights were used to account for the different sampling probabilities and participation rates of the various components of NHANES. Sociodemographic characteristics between SNAP participation and income groups were compared using chi-square tests for categorical variables and univariate regression for continuous variables. Means and distributions of dietary components were estimated using the National Cancer Institute statistical method for usual dietary intake, which accounts for the within-person variation of dietary intake while preserving the complex NHANES weighting scheme.[38] Generalized linear models, assuming a gamma distribution and a log link, were fit to estimate the relative difference in dietary quality.[39] Models adjusted for all study covariates and total energy intake. Dietary weights were used for all analyses of dietary outcomes.

To examine the associations between SNAP participation and cardiometabolic risk factors, multivariable linear and logistic regression models were fit for Z scores and clinical cutpoints, respectively. Mobile Examination Center weights were included in all analyses of BMI, waist circumference, WHtR, HDL cholesterol, and blood pressure. Fasting subsample weights were used in analyses of triglycerides, glucose, and overall cardiometabolic risk, the metabolic syndrome.

Data were analyzed in 2015. All statistical tests were two-sided and significance was considered at $p<0.05$. Statistical analyses were performed with SAS, version 9.3, and StataSE, version 12.

RESULTS

Of the 4,450 adolescents, 22.8% were SNAP participants, 29.5% were income-eligible nonparticipants, and 47.6% were higher-income nonparticipants. Individual and household-level differences between these groups are shown in Table 1. Adolescents participating in SNAP were, on average, younger than income-eligible nonparticipants but not higher-income nonparticipants. Approximately 86% of adolescents participating in SNAP lived below the FPL, compared with 65% of income-eligible nonparticipants. Adolescents participating in SNAP were also more likely to be racial/ethnic minorities, have a parent with fewer years of education, reside in a single-parent household, have a larger household size, and report higher levels of food insecurity than income-eligible and higher-income nonparticipant adolescents.

Compared with national dietary guidelines, very few adolescents consumed the recommended amounts of vegetables, fruits, whole grains, and long-chain fatty acids for optimal health (Table 2). Among all adolescents, the average intake of vegetables was 1.3–1.5 servings/day, of fruits was 0.8–1.0 servings/day, of whole grains was 0.4–0.5 servings/day, and of long-chain fatty acids was 0.04–0.05 g/day. Conversely, many adolescents exceeded the recommended limits for sugary beverages, processed meat, and sodium. The average intake of sugary beverages was 3.0–3.1 servings/day (24–25 fluid ounces/day); 10% of adolescents consumed more than 38–42 fluid ounces/day. For processed meats, the average intake was 0.4 servings/day, with only 40%–45% of adolescents meeting the American Heart Association's recommendation to consume <2 servings/week. The average intake of sodium ranged from 3,232 to 3,457 mg/day, which exceeds the National Academy of Medicine's tolerable upper limit of 2,300 mg/day. Of 110 total points, the average AHEI-2010 score was 33.5 for SNAP participants, 35.0 for income-eligible nonparticipants, and 34.2 for higher-income nonparticipants. Ninety-nine percent of all lower-income adolescents scored ≤50, less than half of the maximum score for optimal diet quality (data not shown).

When comparing SNAP participants with their income-eligible counterparts, SNAP participants consumed significantly less fruit juice (relative difference [RD]=0.72, 95% CI=0.59, 0.88); more processed meats (RD=1.25, 95% CI=1.02, 1.54); and had a lower AHEI-2010 score (RD=0.95, 95% CI=0.91, 0.99). Compared with higher-income nonparticipants, SNAP participants had a lower intake of fruit juice (RD=0.58, 95% CI=0.37, 0.91) and marginally higher intakes of fruit (RD=1.40, 95% CI=0.99, 1.98) and processed meats (RD=1.37, 95% CI=0.97, 1.96). SNAP participants did not differ significantly from either nonparticipant group with respect to intakes of vegetables, whole grains, sugary beverages, nuts and legumes, red meat, long-chain fatty acids, polyunsaturated fat, or sodium.

Table 1. Characteristics of Lower-Income Adolescents (12–19 Years): NHANES 2003–2010

Characteristics	Higher-income nonparticipants, *n*/mean (%/SE) (*n*=1,773)	Low-income nonparticipants, *n*/mean (%/SE) (*n*=1,468)	SNAP participants, *n*/mean (%/SE) (*n*=1,209)	*p*-value[a]
Adolescent characteristics				
Age	15.2 (0.1)	16.0 (0.1)	15.1 (0.08)	**<0.0001**
Female	825 (48.0)	729 (51.4)	603 (50.3)	0.24
Race/ethnicity				
Non-Hispanic white	468 (60.3)	321 (48.2)	208 (38.2)	**<0.0001**
Non-Hispanic black	529 (14.3)	357 (14.6)	561 (31.9)	
Hispanic	688 (18.9)	728 (30.3)	389 (23.8)	
Other or multi-racial	88 (6.5)	62 7.0	51 (6.2)	
Parental characteristics				
Birthplace				**<0.0001**
Born in the U.S.	1,221 (80.0)	793 (66.7)	894 (76.9)	
Born outside of the U.S.	507 (17.5)	621 (30.1)	279 (19.8)	
Educational attainment				**<0.0001**
<12 years	484 (16.5)	622 (33.4)	599 (40.1)	
High school diploma/ equivalent	450 (27.7)	354 (25.7)	335 (33.5)	
Any college	581 (37.9)	354 (30.5)	206 (19.5)	
College graduate	210 (15.4)	72 (6.8)	30 (3.4)	
Missing	48 (2.6)	66 (3.6)	39 (3.4)	
Marital status				**<0.0001**
Married/living with partner	1,130 (67.1)	728 (49.1)	428 (40.5)	
Not partnered	568 (28.2)	609 (40.2)	677 (51.5)	
Missing	75 (2.2)	131 (3.1)	104 (1.8)	
Household characteristics				
Income as ratio to FPL (mean)	2.14 (0.02)	0.77 (0.02)	0.64 (0.01)	**<0.0001**
Income as ratio to FPL				—
0–50% FPL	—	379 (26.9)	445 (33.2)	
50.1–100% FPL	—	626 (37.9)	598 (52.7)	
100.1–130% FPL	—	463 (35.2)	166 (14.1)	
130.1–200% FPL	876 (42.9)	—	—	
200.1–300% FPL	897 (57.1)	—	—	
Household size	4.3 (0.1)	4.3 (0.1)	4.7 (0.1)	**0.001**
WIC participation				—
WIC participant	79 (2.2)	243 (12.5)	365 (26.1)	
Income-eligible nonparticipant	578 (29.0)	1,057 (75.2)	816 (71.2)	
Higher-income nonparticipant	976 (62.2)	0	0	
Missing	140 (6.6)	168 (12.3)	28 (2.7)	
Food security				**<0.0001**
Food secure	1,261 (76.0)	741 (51.3)	588 (51.3)	
Marginally food secure	120 (5.6)	118 (7.1)	190 (14.6)	
Food insecure	212 (8.8)	287 (16.5)	376 (29.4)	
Missing	180 (9.5)	322 (25.1)	55 (4.7)	

Note: Boldface indicates statistical significance ($p<0.05$).
[a]Differences between groups were tested using χ^2 tests for categorical variables and univariate regression for continuous variables.
FPL, federal poverty level; NHANES, National Health and Nutrition Examination Survey; SNAP, Supplemental Nutrition Assistance Program; WIC, The Special Supplemental Nutrition Program for Women, Infants, and Children.

Table 2. Associations Between SNAP Participation and Adolescent Diet Quality: NHANES 2003–2010[a]

Dietary components	M	Median	10th, 90th percentile	% meeting guideline	Relative difference[b] (95% CI)
Vegetables (servings/day)					
Higher-income non-participants	1.3	1.3	0.7, 2.2	0	ref
Income-eligible nonparticipants	1.5	1.4	0.7, 2.4	0	1.07 (0.90, 1.27)
SNAP participants	1.3	1.2	0.6, 2.1	0	1.05 (0.86, 1.28)
Fruit (servings/day)					
Higher-income non-participants	0.8	0.5	0.1, 1.9	0.8	ref
Income-eligible nonparticipants	1.0	0.7	0.1, 2.2	1.2	1.57 (1.19, 2.08)
SNAP participants	0.8	0.6	0.1, 2.0	1.0	1.40 (0.99, 1.98)
100% fruit juice (servings/day)					
Higher-income non-participants	0.3	0.2	0.0, 0.8	–	ref
Income-eligible nonparticipants	0.5	0.3	0.1, 1.1	–	0.81 (0.52, 1.26)
SNAP participants	0.4	0.2	0.0, 0.9	–	0.58[c] (0.37, 0.91)
Whole grains (servings/day)					
Higher-income non-participants	0.5	0.4	0.1, 1.0	0	ref
Income-eligible nonparticipants	0.4	0.3	0.1, 0.9	0	0.96 (0.72, 1.27)
SNAP participants	0.4	0.3	0.1, 0.9	0	0.89 (0.67, 1.19)
Sugary beverages (servings/day)					
Higher-income non-participants	3.0	2.9	1.2, 5.0	2.2	ref
Income-eligible nonparticipants	3.1	2.9	1.3, 5.2	2.3	0.98 (0.81, 1.18)
SNAP participants	3.0	2.8	1.4, 4.8	1.4	1.06 (0.87, 1.29)
Nuts, legumes, and soy (servings/day)					
Higher-income non-participants	0.8	0.6	0.1, 1.8	49.0	ref
Income-eligible nonparticipants	0.8	0.5	0.1, 1.8	48.4	1.05 (0.70, 1.58)
SNAP participants	0.8	0.5	0.1, 1.8	45.4	0.96 (0.61, 1.51)
Red meat (servings/day)					
Higher-income non-participants	0.3	0.3	0.1, 0.6	92.5	ref
Income-eligible nonparticipants	0.4	0.4	0.1, 0.6	90.7	0.90 (0.66, 1.24)
SNAP participants	0.4	0.3	0.1, 0.6	92.5	0.91 (0.65, 1.29)
Processed meat (servings/day)					
Higher-income non-participants	0.4	0.4	0.1, 0.8	39.9	ref
Income-eligible nonparticipants	0.4	0.3	0.1, 0.8	44.5	1.10 (0.81, 1.48)
SNAP participants	0.4	0.4	0.1, 0.8	39.3	1.37[c] (0.97, 1.96)
Long-chain fatty acids (g/day)					
Higher-income non-participants	0.04	0.04	0.02, 0.07	0	ref
Income-eligible nonparticipants	0.05	0.04	0.02, 0.09	0	1.15 (0.70, 1.90)
SNAP participants	0.04	0.04	0.02, 0.07	0	0.91 (0.57, 1.47)
Polyunsaturated fat (% energy)					
Higher-income non-participants	7.1	7.0	5.4, 8.9	–	ref
Income-eligible nonparticipants	7.3	7.2	5.6, 9.1	–	1.03 (0.94, 1.14)
SNAP participants	7.2	7.0	5.4, 9.0	–	0.99 (0.89, 1.10)
Sodium (mg/day)					
Higher-income non-participants	3445	3353	2294, 4721	9.7	ref
Income-eligible nonparticipants	3457	3357	2297, 4739	9.6	0.98 (0.93, 1.04)
SNAP participants	3232	3139	2138, 4442	14.0	0.99 (0.94, 1.04)
Alternate Healthy Eating Index–2010 score					
Higher-income non-participants	34.2	33.9	26.8, 41.8	–	ref
Income-eligible nonparticipants	35.0	34.8	27.5, 42.9	–	1.03 (0.97, 1.09)
SNAP participants	33.5	33.2	26.2, 41.1	–	0.97[c] (0.92, 1.04)

Note: Boldface indicates statistical significance ($p < 0.05$).
[a]Diet quality assessed using the Alternate Healthy Eating Index–2010.
[b]Relative difference obtained from generalized linear models adjusted for adolescent's age, adolescent's gender, adolescent's race/ethnicity, parental birthplace, parental educational attainment, parental marital status, household size, household income, household WIC participation, household food insecurity, and total energy intake.
[c]$p < 0.05$ comparing SNAP participants to income-eligible nonparticipants.
NHANES, National Health and Nutrition Examination Survey; SNAP, Supplemental Nutrition Assistance Program.

Table 3. Associations Between SNAP Participation and Adolescent Anthropometric Measures of Adiposity: NHANES 2003–2010

	Continuous measure		Clinical definition[a]	
Measures	**M ± SE**	**Multivariate-adjusted,[b] β (95% CI)**	***n* (%)**	**Multivariate-adjusted,[b] OR (95% CI)**
BMI-for-age Z score[c]				
Higher-income nonparticipants	0.59 ± 0.04	ref	359 (19.0)	ref
Income-eligible nonparticipants	0.56 ± 0.05	0.11 (−0.05, 0.28)	295 (18.6)	1.15 (0.83, 1.59)
SNAP participants	0.74 ± 0.05	**0.21 (0.01, 0.41)**	303 (27.5)	**1.59 (1.06, 2.39)**
Waist circumference Z score[d]				
Higher-income nonparticipants	−0.05 ± 0.04	ref	486 (33.6)	ref
Income-eligible nonparticipants	0.03 ± 0.05	0.09 (−0.06, 0.25)	447 (32.1)	1.21 (0.87, 1.68)
SNAP participants	0.08 ± 0.04	**0.21 (0.03, 0.39)**	364 (33.6)	1.48 (0.96, 2.27)
Waist-to-height ratio				
Higher-income nonparticipants	0.49 ± 0.003	ref	652 (37.1)	ref
Income-eligible nonparticipants	0.50 ± 0.004	0.01 (−0.01, 0.02)	604 (39.7)	1.01 (0.75, 1.38)
SNAP participants	0.51 ± 0.004	**0.02 (0.00, 0.03)**	482 (43.6)	1.21 (0.80, 1.82)

Note: Boldface indicates statistical significance ($p<0.05$).
[a]Obesity was defined as BMI-for-age ≥95th percentile; elevated waist circumference was defined as a waist circumference ≥90th percentile specific to their age, sex, and ethnicity; elevated waist-to-height ratio was defined as waist-to-height ratio >0.50.
[b]Model adjusted for adolescent's age, adolescent's gender, adolescent's race/ethnicity, parental birth place, parental educational attainment, parental marital status, household size, household income, household WIC participation, and household food insecurity.
[c]BMI-for-age z score derived from age- and sex-specific percentiles using the 2000 Centers for Disease Control and Prevention growth charts
[d]Waist circumference z score derived from analytic sample.
NHANES, National Health and Nutrition Examination Survey; SNAP, Supplemental Nutrition Assistance Program; WIC, The Special Supplemental Nutrition Program for Women, Infants, and Children.

Associations between SNAP participation and anthropometric measures of adiposity are shown in Table 3. Among adolescent SNAP participants, 27.5% had a BMI-for-age ≥95th percentile, 33.6% had an elevated waist circumference, and 43.6% had an elevated WHtR. Compared with higher-income nonparticipants, adolescent SNAP participants had a higher BMI-for-age Z score (β=0.21, 95% CI=0.01, 0.41) and higher odds of obesity (OR=1.59, 95% CI=1.06, 2.39) after multivariate adjustment. These trends were also true for other measures: SNAP participants also had a higher waist circumference Z score (β=0.21, 95% CI=0.03, 0.39) and a higher WHtR (β=0.02, 95% CI=0.00, 0.03) than higher-income nonparticipants. When compared with income-eligible nonparticipants, adolescent SNAP participants had a marginally higher odds of obesity (OR=1.38, 95% CI=0.97, 1.96, p=0.07).

Associations between adolescent SNAP participation and cardiometabolic risk factors are shown in Table 4. Among SNAP participants, 30% had low HDL cholesterol, 11% had elevated fasting triglycerides, and 17% had elevated fasting glucose. Although there were no significant differences with respect to most risk factors, the mean values suggested trends consistent with poorer cardiometabolic health among SNAP participants, compared with both income-eligible and higher-income nonparticipants. After adjustment for sociodemographic factors and household food insecurity, there was a significantly higher overall cardiometabolic risk Z score relative to higher-income nonparticipants (β=0.75, 95% CI=0.02, 1.49) and income-eligible nonparticipants (β=0.55, 95% CI=0.03, 1.08).

DISCUSSION

In this nationally representative sample of lower-income adolescents, most fell short of meeting dietary guidelines aimed at promoting health, and exceeded limits on foods and nutrients known to increase the risk of weight gain and chronic disease. Although most individual dietary components of the AHEI-2010 were not significantly different between groups, adolescent SNAP participants had a significantly lower AHEI-2010 score, compared with their income-eligible counterparts. These dietary results underscore the vast room for improvement and

Table 4. Associations Between SNAP Participation and Adolescent Cardiometabolic Health: NHANES 2003–2010

Measures	Continuous measure[a] M ± SE Boys	Girls	Multivariate-adjusted,[c] β (95% CI)	Clinical definition[b] n (%) Boys	Girls	Multivariate-adjusted,[d] OR (95% CI)
Systolic blood pressure (in mmHg)						
Higher-income nonparticipants	112.7 ± 0.5	107.2 ± 0.4	ref	60 (3.9)	10 (2.1)	ref
Income-eligible nonparticipants	112.6 ± 0.7	107.0 ± 0.5	0.02 (−0.13, 0.18)	39 (4.8)	9 (0.8)	0.93 (0.46, 1.87)
SNAP participants	111.7 ± 0.6	107.2 ± 0.6	0.03 (−0.14, 0.20)	26 (7.3)	10 (1.1)	1.09 (0.44, 2.71)
Fasting triglycerides (in mg/dL)						
Higher-income nonparticipants	88.1 ± 3.6	87.7 ± 4.2	ref	41 (9.9)	28 (11.3)	ref
Income-eligible nonparticipants	91.9 ± 4.3	87.3 ± 4.2	−0.02 (−0.23, 0.20)	31 (12.5)	22 (9.5)	1.09 (0.40, 2.94)
SNAP participants	92.5 ± 5.0	88.2 ± 4.6	0.10 (−0.11, 0.31)	23 (11.4)	19 (9.8)	1.37 (0.49, 3.79)
HDL cholesterol (in mg/dL)						
Higher-income nonparticipants	49.0 ± 0.5	54.3 ± 0.7	ref	198 (23.7)	194 (25.6)	ref
Income-eligible nonparticipants	49.2 ± 0.7	54.4 ± 0.6	−0.03 (−0.21, 0.15)	166 (24.5)	175 (24.4)	1.02 (0.70, 1.49)
SNAP participants	49.5 ± 0.7	52.4 ± 0.7	−0.13 (−0.32, 0.06)	136 (28.8)	194 (31.5)	1.36[f] (0.86, 2.17)
Fasting glucose (in mg/dL)						
Higher-income nonparticipants	96.4 ± 1.0	91.7 ± 0.6	ref	85 (24.3)	28 (10.6)	ref
Income-eligible nonparticipants	96.1 ± 1.6	91.5 ± 0.7	0.12 (−0.13, 0.36)	66 (21.3)	33 (11.5)	0.96 (0.48, 1.90)
SNAP participants	96.7 ± 2.0	94.3 ± 2.1	**0.29 (0.04, 0.53)**	85 (21.4)	24 (13.0)	1.15 (0.56, 2.35)
Cardiometabolic risk (Z score)[e]						
Higher-income nonparticipants	0.7 ± 0.2	−0.5 ± 0.2	ref	28 (7.3)	16 (6.0)	ref
Income-eligible nonparticipants	0.6 ± 0.2	−0.5 ± 0.2	0.20 (−0.40, 0.80)	19 (6.9)	16 (5.2)	1.16 (0.51, 2.60)
SNAP participants	0.5 ± 0.3	−0.2 ± 0.3	**0.75[f] (0.02, 1.49)**	17 (7.9)	12 (4.8)	1.59 (0.67, 3.77)

Note: Boldface indicates statistical significance ($p<0.05$).
[a]Z scores derived from analytic sample.
[b]International Diabetes Federation criteria used to define age-appropriate clinical cutpoints for cardiometabolic risk factors:Waist circumference ≥90th percentile or BMI-for-age ≥95th percentile and the presence of ≥2 risk factors: elevated triglycerides (≥150 mg/dL); low-HDL cholesterol (<40 mg/dL in boys, <50 mg/dL in girls); elevated blood pressure (≥130/≥85 mmHg); and elevated fasting glucose (≥100 mg/dL).
[c]Multivariate linear regression models were fit for continuous measures converted to Z scores and adjusted for adolescent's age, adolescent's gender, adolescent's race/ethnicity, parental birth place, parental educational attainment, parental marital status, household size, household income, household WIC participation, and household food insecurity.
[d]Multivariate logistic regression models adjusted for adolescent's age, adolescent's gender, adolescent's race/ethnicity, parental birthplace, parental educational attainment, parental marital status, household size, household income, household WIC participation, and household food insecurity.
[e]As a continuous outcome, cardiometabolic risk was defined as the summation of the systolic blood pressure, fasting triglycerides, HDL cholesterol (inverse), and fasting glucose Z scores, with a higher score denoting higher cardiometabolic risk. As a dichotomous outcome, the metabolic syndrome was defined as waist circumference ≥90th percentile or BMI-for-age ≥95th percentile, and the presence of adverse levels of ≥2 risk factors.
[f]$p<0.05$ comparing SNAP participants to income-eligible nonparticipants.
HDL, high-density lipoprotein; NHANES, National Health and Nutrition Examination Survey; SNAP, Supplemental Nutrition Assistance Program; WIC, Special Supplemental Nutrition Program for Women, Infants and Children.

the importance of national programs and policies that can promote opportunities for healthier eating among all lower-income families.

Relative to both income-eligible and higher-income nonparticipants, adolescent SNAP participants had significantly higher levels of obesity, consistent across anthropometric measures of both central and overall adiposity. The economic, mental, and physical consequences of adolescent obesity have been well documented, including stark increases in the risks of obesity and coronary heart disease in adulthood.[40–43] In this study, adolescent SNAP participants did not differ clinically on most cardiometabolic risk factors, though they did have significantly higher overall cardiometabolic risk scores when compared with both ref groups. Although these associations with overall cardiometabolic risk were modest, the CIs for these results highlight the disparities across multiple cardiometabolic indicators that could be exacerbated among adolescent SNAP participants as they approach adulthood. Given this critical period, SNAP-like interventions that promote healthful eating behaviors and reduce obesity may be doubly important for their potential to improve dietary behaviors during adolescence and reduce future disparities in cardiometabolic disease.

The cross-sectional nature of the data precludes causal inferences. Although it is possible that the nature of SNAP participation facilitates dietary behaviors that promote chronic disease, particularly in the larger context of the low-income food environment,[44,45] an equally plausible explanation may be that SNAP participation is a marker of severe vulnerability to poverty, food insecurity, and inadequate nutrition. The U.S. Department of Agriculture estimates that two thirds of all SNAP participants are children, elderly, or disabled people and the majority of SNAP participants live below the FPL.[1] In a study of Massachusetts SNAP participants, more than 70% of adults reported food insecurity at the time of SNAP enrollment.[46] Conversely, studies of eligible SNAP nonparticipants have found that many income-eligible nonparticipants live in married households and higher-income neighborhoods,[47] have other financial support, have higher educational attainment,[48] or simply report not needing SNAP despite meeting the income eligibility criteria.[49] Several of these demographic differences were observed in this study as well, indicating that this vulnerability extends to low-income adolescents as well as their adult caregivers. This suggests that SNAP serves low-income children and families who are truly in need of nutrition assistance and are also at the greatest risk for diet-related chronic disease.

Given that SNAP is already a national intervention aiming to improve food security and nutrition, policies have been proposed to strengthen its nutritional impact. These include providing incentives for healthful foods, removing sugary beverages from the list of products purchased with SNAP benefits, enhancing the nutrition education program, and providing more total benefits.[50] These policies have garnered majority support from key stakeholder groups,[51,52] including SNAP participants.[46,53,54] Results of the Healthy Incentives Pilot demonstrated that providing financial incentives for fruits and vegetables can change purchasing and consumption patterns.[55] However, it is unlikely that incentives alone, like the Healthy Incentives Pilot, which resulted in a 0.24-cup daily increase in fruits and vegetables, can boost the diet and health behaviors of SNAP participants to the levels of income-eligible nonparticipants, much less to the levels needed to protect against the adverse effects of poverty on health. Similarly, there is evidence to suggest that SNAP benefit levels are inadequate, with many families running out of food before the end of the month.[56] Increasing SNAP benefit allotments is likely to have favorable effects on food insecurity and dietary intake. A 2013 National Academy of Medicine (NAM) report recommended that the determination of SNAP benefit allotments should consider "specific individual, household, and environmental factors on [SNAP] participants' purchasing power."[57] To identify policies that would have the most beneficial impact both on participants' health, an important next step is to conduct evidence-based interventions comparing multiple strategies against the status quo, such as incentives for healthful foods consistent with the dietary guidelines, restrictions of sugary beverages, and comprehensive nutrition education, all of which were recommended in a recent National Commission on Hunger report.[58]

Limitations

Other limitations of this study include the possibility for misclassification of SNAP participation status and unmeasured confounding by factors associated with food insecurity and cardiometabolic health. SNAP participation may be highly variable throughout the year—program participants can lose benefits because of changes in their income or other circumstances, programmatic changes, or system errors. The unexpected loss of SNAP benefits has been associated with adverse children's developmental and health outcomes. Future studies should attempt to isolate these effects from the overall associations of SNAP participation and cardiometabolic health.[59,60] Many prior studies have also found associations between food insecurity and children's mental health, including greater adversity,[61,62] more behavioral problems,[63–66] worse psychosocial functioning,[67–69] and higher rates of depression and suicidal thoughts.[70] Similarly, environmental factors like the food environment, neighborhood walkability, and exposures to other environment stressors are often correlated with SES and may influence children's cardiometabolic health.[71–73] These psychosocial and neighborhood-level measures are not available in the NHANES public use data files but should be incorporated in future studies to better understand the complexities of the associations observed. Lastly, although 24-hour dietary recalls are self-reported and generally underestimate total energy intake,[74] there is no reason that this would be differential by SNAP participation status.

CONCLUSIONS

SNAP is a critical program that protects low-income families from food insecurity. However, the results of this study suggest that most lower-income adolescents have poor diet quality, high levels of obesity, and adverse cardiometabolic profiles, with some evidence that adolescent SNAP participants are at greater risk. Stakeholder-supported policies to strengthen the nutritional impact of SNAP deserve further consideration. With its broad reach, SNAP has the potential to influence the diets of millions of children and adolescents, and thus represents a unique opportunity to reduce disparities and improve the lifelong health of those most vulnerable to food insecurity and poor nutrition.

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