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Neighborhood socio-economic status and cross-sectional associations with obesity and urinary biomarkers of diet among New York City adults: The Heart Follow-up Study.

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Neighborhood socio-economic status and cross-sectional associations with obesity and urinary biomarkers of diet among New York City adults: The Heart Follow-up Study.

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ABSTRACT

Objective: To determine whether neighborhood socio-economic status (SES) is associated with body mass index (BMI), waist circumference, and urinary sodium, and potassium excretion.

Design: A cross-sectional study.

Setting: The data reported were from the 2010 Heart Follow Up Study, a population based representative survey of 1,645 adults.

Participants: Community dwelling diverse residents of New York City nested within 128 neighborhoods (zip codes).

Primary and secondary outcome measures: BMI (kg/m^2) and waist circumference (inches) were measured during in-home visits, and 24-hour urine was collected to measure sodium and potassium.

Results: After adjusting for individual-level characteristics using multilevel linear regressions, low vs. high neighborhood SES tertile was associated with 1.83 kg/m^2 higher body mass index (95% CI: 0.41, 3.98) and 251 mg/day lower potassium excretion (95% CI: -409,-93) among women only, with no associations among men (p-values for neighborhood SES by sex interactions <0.05).

Conclusion: Our results suggest women may be particularly vulnerable to the effects of a socioeconomically disadvantaged neighborhood. Future neighborhood research should explore sex differences, as these can inform tailored interventions.

Trial Registration: This trial is registered at clinicaltrials.gov as NCT01889589.

Strengths and Limitations of this study:

- These data come from the New York City Heart Follow-Up Study, and are population based and representative of the New York City adult population.
- Modeled as tertiles of a factor score, the main exposure of interest, neighborhood socio-economic status, was constructed based on neighborhood levels of education, poverty, unemployment, and safety.
- All outcomes were measured objectively and included measured body mass index, waist circumference, and 24-hour urinary excretion derived measures of sodium, potassium, and sodium to potassium ratio.
- Data were cross-sectional and therefore temporality was not established; additionally the paper does not account for self-selection of certain individuals into certain neighborhoods.

INTRODUCTION:

Poor socio-economic status (SES) has been linked to both higher rates of obesity [1] and poor dietary quality,[2] particularly among women.[1] Mechanisms behind such associations include poverty being associated with unhealthy behaviors[3] and greater exposure to stress-inducing mechanisms.[4] For example, for individuals of low SES, cost is often a barrier to a healthy diet, and therefore, such individuals are more likely to consume less nutritious and more calorie-dense food.[5] However, the extent to which modifying characteristics or behaviors at the individual-level would be successful for achieving better diet quality and lower obesity rates, especially among individuals living in disadvantaged environments, remains unclear.

Beyond individual-level mechanisms, a growing body of research suggests that neighborhood characteristics, such as neighborhood safety and neighborhood SES, may also influence obesity[6-9] and diet quality.[10-14] For example, findings from the landmark Moving To Opportunity study showed that altering the socioeconomic environment by relocating into a higher income neighborhood was associated with a lower prevalence of obesity[15] and improved physical health outcomes in youth girls but not boys.[16] Studies[10-12,17] pointing to a relationship between the neighborhood environment and diet quality have mainly used subjective measures of diet such as healthy eating indices or self-reported fruit and vegetable intake which can be prone to measurement error.[18] To our knowledge, only two previous studies of neighborhood and diet[13,19] have included objectively measured biomarkers of diet quality such as sodium and potassium.[20,21] Furthermore, while it is suggested that neighborhood effects might differ by sex, the relationships between the neighborhood socioeconomic environment with obesity and diet quality are seldom explored by sex and results have been mixed.[16,22-27]

Leveraging data from the Heart Follow-Up Study (HFUS), a population based study of New York City (NYC) adult residents, the objective of our analysis was to examine the association between neighborhood SES and measures of obesity – as body mass index and waist circumference – and diet quality – as 24-hour urine derived biomarkers of sodium, potassium, and sodium to potassium (Na-K) ratio. We also examined whether these associations varied by sex.

METHODS

Study design and study sample

The New York City Community Health Survey (CHS) Heart Follow-Up Study (HFUS), is a cross-sectional study conducted in 2010 to assess population-based sodium intake from a representative sample of 1,775 NYC adults ages 18 years or older.[28] Study participants in the HFUS were recruited from the CHS parent study, which is an annual telephone survey conducted by the NYC Health Department that includes 8,000 to 10,000 adult New Yorkers each year.[29] To obtain a representative sample of non-institutionalized adult New Yorkers, the CHS uses a dual frame sample design consisting of random-digit-dial landline and cellular telephone exchanges that cover NYC and incorporates a disproportionate stratified random sample design. In brief, study participants in the HFUS answered survey questions and collected urine for a 24-hour period. During a home visit, a trained medical technician took anthropometric measurements, aliquotted the urine, and sent it directly to the research laboratory. All study participants provided informed consent and IRB approval was obtained at both the Univeristy of Miami and the NYC Health Department.

Measures of obesity

During in-home visits, HFUS participants' weight and height was recorded without shoes. BMI was calculated as measured weight in kilograms divided by measured height in meters-squared. Waist circumference (WC) was measured in inches as waist girth at the top of the lateral border of the right ilium.

Biomarkers of Diet Quality: urinary sodium and potassium

HFUS participants provided 24-hour urine samples which were sent to the collaborating laboratory at the Mount Sinai Hospital and Medical School and analyzed for sodium, potassium, and creatinine. Sodium and potassium were measured using the ion-selective electrode potentiometric method on the Roche DPP Modular analyzer. Creatinine, used to assess urine completeness,[20] was measured using the Jaffe kinetic colorimetric method on the same analyzer. All laboratory values were normalized to a 24-hour collection period (mg/day). Na-K ratio was defined as the ratio between sodium (mg/day) and potassium (mg/day). Higher sodium, lower potassium, and higher Na-K ratio are indicative of worse diet quality.[20,21]

Other individual-level measures

Through survey questionnaires, HFUS participants reported their age in age groups (18-24, 25-44, 45-64, or 65+ years), sex, and race/ethnicity (white non-hispanic, black non-hispanic, hispanic, asian, or other). Participants reported family size as the number of individuals per household, and also reported whether their household income from all sources was less than 100%, 100 – 199%, 200 – 299%, 300 – 399%, 400 – 499%, 500 – 599%, or 600% or more of the Federal Poverty Level (FPL). For reference, the FPL in 2010 for a household of four people was $22,050.[30] Participants also reported their educational attainment defined as less than high school (HS), HS graduate, some college, or college graduate or more. Employment status was recorded and defined as employed, unemployed, or not in the labor force.

Participants also answered a series of questions about their physical activity which were used to calculate their total minutes of moderate and vigorous physical activity.[31] Participants who reported an average of 150 moderate or 75 vigorous minutes of physical activity per week were considered to have met 2008 physical activity guidelines.[32]

Neighborhood SES

Neighborhoods were defined according to zip codes which were retrieved from participants' addresses. We used factor analysis to create a neighborhood SES factor score using zip code level variables. The prinicple factor method was used to estimate factor scores, and a loading threshold of 0.3 was set to indicate whether a variable should be retained. The final selected variables included: percentage of households in the neighborhood with income 100% below the FPL, percentage of individuals in the neighborhood who are unemployed, percentage of individuals in the neighborhood with less than a HS education, and percentage of individuals in the neighborhood who report living in an unsafe neighborhood. Neighborhood safety was reported in response to the question of "How safe from crime do you consider your neighborhood to be" with responses including "extremely safe," "quite safe," "slightly safe," or "not safe at all"; answers were then dichotomized into two categories: an unsafe neighborhood ("slightly safe" or "not safe at all" responses) vs. a safe neighborhood ("extremely safe" or "quite safe" responses). We then created tertiles from the neighborhood SES score to further characterize neighborhoods as having low SES (disadvantageous), middle SES, or high SES (advantageous).

Statistical Analyses

Of the original 1775 individuals who provided urine samples, a total of 119 were excluded due to an incomplete or biologically implausible urine sample, defined using the following criteria: total urine volume <500 mL, creatinine <6.05 mmol for men or <3.78 mmol for women, or a participant reporting missing a collection.[20] An additional 11 individuals were excluded due to lack of geographic residence (zip code) information, resulting in a final analytic sample of 1645 individuals.

The data structure of this analysis includes 2 levels: 1645 individuals in level 1 nested within 128 neighborhoods in level 2. We first assessed individual-level characteristics of the sample overall and by sex. We then assessed neighborhood-level characteristics overall and across tertiles of the neighborhood SES score. Next we estimated mean obesity (BMI and WC) and mean dietary characteristics (sodium, potassium, and Na-K ratio) across tertiles of neighborhood SES score, for women and men separately. All means and proportions were age standardized to the US 2010 population so that they could be compared to national US population.

To determine whether a multi-level model and analyses were appropriate, we calculated intraclass correlation coefficients which calculate for each outcome of interest the percent of total variance that is between neighborhoods. Intraclass correlations were 4.4%, 3.6%, 0.17%, 6.6%, and 8.0% respectively for BMI, WC, sodium, potassium, and Na-K ratio, indicating sufficient neighborhood level clustering for all outcomes but sodium; a multilevel analysis was then deemed appropriate. We then fit multi-level linear regression models to determine whether neighborhood SES score (as tertiles) was associated with each of BMI, WC, sodium, potassium, and Na-K ratio. We tested for effect modification by sex in unadjusted models; neighborhood SES by sex interactions were significant for outcomes of WC ($p<0.05$) and potassium ($p<0.05$), all models were then stratified by sex. We adjusted for individual level age, race/ethnicity, education, poverty, employment status, physical activity (for BMI and WC models), and BMI (for sodium, potassium, and Na-K models). Data were analyzed in 2016 with survey weights and design variables using SUDAAN (version 10.0; Research Triangle Institute, Research Triangle Park, North Carolina) and MPLUS (Version 7; Muthen and Muthen 1998-2012).

RESULTS

Approximately 13.3% of the sample was 18-24 years of age, 44% were ages 25-44 years, 28% were 45-64 years, and 15% were 65 years or older (Table 1). A total of 39% of the population was non-Hispanic White, 23% was non-Hispanic Black, 24% was Hispanic, and 10% was Asian. Approximately 21% had less than a HS education, 48% were below 200% of the FPL, and 10% were unemployed. A total of 62.1% of the population met 2008 PA guidelines. Compared with men, women were more likely to have less than a HS education and be in poverty, and less likely to be employed.

Table 1. Individual-level characteristics of the study sample, overall and by sex.

	Overall (N=1645)		Men (n=689)		Women (n=956)	
	%	SE	%	SE	%	SE
Characteristic						
Age group						
18-24	13.3	1.6	14.0	2.4	12.6	2.3
25-44	43.5	2.0	45.4	3.1	41.8	2.7
45-64	27.9	1.6	27.7	2.4	28.0	2.2
65+	15.4	1.2	12.9	1.6	17.5	1.8
Race/Ethnicity						
White	39.0	1.7	45.8	2.6	**33.5****	**2.3**
Black	23.4	1.5	21.9	2.2	24.4	2.2
Hispanic	23.6	1.6	16.9	2.0	**29.3****	**2.4**
Asian	10.3	1.4	11.4	2.3	9.4	1.6
Other	3.7	1.4	4.0	1.3	3.5	1.1
Less than HS Education						
< HS	21.3	1.7	17.6	2.4	**24.5***	**2.5**
HS	27.0	1.8	27.6	2.7	26.7	2.4
Some college	22.0	1.5	23.4	2.4	20.7	2.0
College grad	29.6	1.5	31.3	2.4	28.1	2.0
Poverty						
< 200% FPL	48.1	1.9	41.9	2.9	**53.0****	**2.6**
≥200% FPL	45.9	1.8	54.0	2.7	**39.2****	**2.4**
Don't know/Refused	6.0	1.1	4.1	1.2	7.7	1.9
Employment						
Employed	56.7	1.8	62.6	2.3	**51.2****	**2.6**
Unemployed	10.4	1.2	10.8	1.6	10.1	1.6
Not in labor force	32.9	1.6	26.6	1.9	**38.7****	**2.4**
Meets 2008 Physical Activity	62.1	1.9	65.3	2.6	58.9	2.7

[a] Estimates are age standardized to the US 2000 population.
Abbreviations: FPL: federal poverty level; HS: high school; SE: standard error.
Boldface indicates statistical significant differences comparing men with women (** *P*<0.01, **P*<0.05)

The proportion of households with income <100% of the FPL and the proportion of individuals reporting living in an unsafe neighborhood was highest (38% and 56% respectively) in the lowest neighborhood SES score tertile and lowest in the highest neighborhood SES tertile (6% and 10% respectively), data not shown. Likewise, the proportion of individuals who were unemployed or with less than a HS education was highest (12% and 27% respectively) in the lowest neighborhood SES tertile and lowest in the highest neighborhood SES tertile (6% and 7% respectively).

Mean 24-hour urinary sodium excretion was 3240 mg/day and did not differ significantly by neighborhood tertile in men or women (Table 2). Among men, those living in a low vs. high SES neighborhoods had significantly lower mean urinary potassium excretion (2131 vs. 2404 mg, $p<0.01$), and higher mean Na-K ratio (1.92 vs. 1.61, $P=0.01$). Among women, those living in a low vs. high SES neighborhood had higher mean BMI (29.3 vs. 26.1 kg/m^2, $p<0.01$), higher mean WC (36.4 vs. 32.9 inches, $p<0.01$), and lower mean urinary potassium excretion (1911 vs. 2238, $p<0.01$). Similarly, women living in middle vs. high SES neighborhoods also had significantly higher mean BMI (28.3 vs. 26.1 kg/m^2, $p<0.01$), higher mean WC (35.8 vs. 32.9 inches, $p<0.01$), and lower mean urinary potassium excretion (1890 vs. 2238, $p<0.01$).

Table 2. Mean obesity and dietary characteristics overall and across tertiles of neighborhood SES score, by sex [a]

	Overall		Men: Tertile of Neighborhood SES Score — Low (n=216)		Middle (n=258)		High (n=215)		Women: Tertile of Neighborhood SES Score — Low (n=422)		Middle (n=304)		High (n=230)	
	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
BMI (kg/m2)	28.2	0.3	28.6	0.5	28.6	0.8	27.3	27.3	**29.3****	**0.5**	**28.3****	**0.5**	26.1	0.5
Waist Circumference (inches)	36.3	0.2	37.6	0.5	37.6	0.7	36.9	0.5	**36.4****	**0.4**	**35.8****	**0.5**	32.9	0.4
Sodium (mg/day)	3,240	58	2,699	159	3,734	134	3,377	159	2,961	106	2,865	108	3,013	150
Potassium (mg/day)	2,182	38	**2,131***	**87**	2,667	135	2,404	92	**1,911****	**63**	**1,890****	61	2,238	95
Na-K Ratio	1.68	0.03	**1.92***	**0.08**	1.63	0.08	1.61	0.10	1.73	0.07	1.70	0.08	1.52	0.09

[a] Estimates are age standardized to the US 2000 population.

Abbreviations: Na-KSE: standard error; SES: socio-economic status

Boldface indicates statistical significant differences when compared to high neighborhood SES using T-tests (** P<0.01, * P<0.05)

In multilevel models, neighborhood SES was not associated with individual-level BMI or WC among men (Table 3). Among women, in unadjusted models, living in a low vs. high SES neighborhood was significantly associated with 3.60 kg/m^2 higher BMI [95% Confidence interval (CI): 2.00, 5.19] and 2.94 inches larger WC (95% CI: 0.80, 5.09). Likewise, living in a middle vs. high neighborhood SES was significantly associated with 2.21 kg/m^2 higher BMI (95% CI: 1.00, 3.43) and 2.00 inches larger WC (95% CI: 0.46, 3.58). In fully adjusted models, living in a low vs. high SES neighborhood remained associated with 2.19 inches higher BMI (95% CI: 0.41, 3.98), while living in a middle vs. high neighborhood SES remained significantly associated with 1.83 kg/m^2 higher BMI (95% CI: 0.34, 3.31) and 1.86 inches larger WC (0.22, 3.50).

Table 3. Associations of tertiles of neighborhood SES score with BMI and waist circumference, by sex.

	BMI (kg/m^2)				Waist Circumference (inches)			
	Men		Women		Men		Women	
	Beta	95% CI	Beta	95% CI	Beta	95% CI	Beta	95% CI
Model 1 [a]								
Neighborhood SES								
Low	1.17	-0.39, 2.74	**3.60****	**2.00, 5.19**	0.19	-1.42, 1.81	**2.94***	**0.80, 5.09**
Middle	1.12	-1.69, 3.93	**2.21****	**1.00, 3.43**	0.18	-1.77, 2.13	**2.00***	**0.46, 3.58**
High	Ref		Ref		Ref		Ref	
Model 2								
Neighborhood SES								
Low	0.92	-0.63, 2.47	**2.37****	**0.84, 3.89**	0.55	-1.24, 2.33	**2.21***	**0.19, 4.24**
Middle	1.00	-1.47, 3.47	**1.79****	**0.49, 3.10**	0.35	-1.52, 2.23	**1.83***	**0.27, 3.39**
High	Ref		Ref		Ref		Ref	
Model 3								
Neighborhood SES								
Low	0.62	-1.11, 2.35	**2.25****	**0.70, 3.80**	0.18	-1.74, 2.09	**2.07***	**0.01, 4.14**
Middle	0.85	-1.56, 3.25	**1.65***	**0.36, 2.94**	0.29	-1.57, 2.14	**1.69***	**0.05, 3.33**
High	Ref		Ref		Ref		Ref	
Model 4								
Neighborhood SES								
Low	0.59	-1.06, 2.23	**2.19***	**0.41, 3.98**	0.17	-1.66, 1.99	2.12	-0.11, 4.34
Middle	1.07	-1.33, 3.48	**1.83***	**0.34, 3.31**	0.46	-1.39, 2.31	**1.86***	**0.22, 3.50**
High	Ref		Ref		Ref		Ref	

[a] Model 1 is unadjusted; model 2 is adjusted for individual-level age, and race/ethnicity; Model 3 is additionally adjusted for individual-level education, poverty, and employment status; model 4 is additionally adjusted for physical activity.
Abbreviations: CI: confidence interval; SES: socio-economic status.
Boldface indicates statistical

Among men, neighborhood SES was associated with individual level potassium and Na-K ratio from unadjusted multi-level models (Table 4). In particular, living in a low vs. high SES neighborhood was significantly associated with 403 mg/day less potassium excretion (95% CI: -628, -178) and 0.40 (95% CI: 0.13, 0.66) unit higher Na-K ratio in unadjusted models only. Among women, from unadjusted multilevel models, living in a low or middle SES neighborhood vs. high SES neighborhood was significantly associated with 426 mg/day (95% CI: -614, -238) and 425 mg/day (95% CI: -604, -245) less potassium excretion, respectively. Likewise low vs. high SES neighborhood was associated with 0.36 (95% CI: 0.16, 0.56) units higher Na:K ratio among women. In fully-adjusted models, among women, living in a low or middle SES neighborhood vs. high SES neighborhood remained significantly associated with 251 mg/day (95% CI: -409, -93) and 330 mg/day (95% CI: -501, -159) less potassium excretion, respectively.

Table 4. Associations of tertiles of neighborhood SES score with urinary sodium, potassium, and Na-K excretion by sex.

	Sodium (mg/day)				Potassium (mg/day)				Sodium to Potassium Ratio			
	Men		Women		Men		Women		Men		Women	
	Beta	95% CI	Beta	95% CI	Beta	95% CI	Beta	95% CI	Beta	95% CI	Beta	95% CI
Model 1 [a]												
Neighborhood SES												
Low	12	-426, 451	42	-217, 301	**-403****	**-628, -178**	**-426****	**-614, -238**	**0.40****	**0.13, 0.66**	**0.36****	**0.16, 0.56**
Middle	64	-410, 538	-61	-318, 195	-14	-235, 208	**-425****	**-604, -245**	0.1[illegible]	-0.10, 0.36	0.27	0.05, 0.49
High	Ref		Ref		Ref		Ref		Ref		ref	
Model 2												
Neighborhood SES												
Low	-2	-512, 508	-116	-362, 129	-98	-323, 127	**-266****	**-446, -86**	0.11	-0.13, 0.34	0.09	-0.08, 0.27
Middle	77	-335, 489	-156	-416, 103	235	-101, 571	**-331****	**-509, -152**	-0.08	-0.33, 0.17	0.13	-0.04, 0.30
High	Ref		Ref		Ref		Ref		Ref		ref	
Model 3												
Neighborhood SES												
Low	-21	-591, 550	-130	-404, 144	31	-195, 257	**-244****	**-415, -73**	0.05	-0.19, 0.29	0.04	-0.13, 0.21
Middle	80	-325, 486	-183	-452, 87	319	-13, 651	**-328****	**-507, -148**	-0.11	-0.34, 0.12	0.10	-0.07, 0.26
High	Ref		Ref		Ref		Ref		Ref		ref	
Model 4												
Neighborhood SES												
Low	78	-478, 545	-205	-475, 64	47	-180, 274	**-251****	**-409, -93**	0.04	-0.19, 0.28	-0.01	-0.19, 0.16
Middle	168	-347, 1775	-227	-478, 24	**313***	**9, 618**	**-330****	**-501, -159**	-0.1[illegible]	-0.35, 0.11	0.06	-0.11, 0.24
High	Ref		Ref		Ref		Ref		Ref	ref		

[a] Model 1 is unadjusted; model 2 is adjusted for individual-level age, and race/ethnicity; Model 3 is additionally adjusted for individual-level education, poverty, and employment status; model 4 is additionally adjusted for physical activity.

Abbreviations: CI: confidence interval; Na-K: sodium to potassium ratio; SES: socio-economic status.

Boldface indicates statistical significance (** *P*<0.01; * *P*<0.05)

DISCUSSION

Findings from this study suggest strong associations between lower neighborhood SES and higher BMI and WC, and lower urinary potassium excretion among women but not men. Among women, residing in a low vs. high SES neighborhood was associated with a 2.19 kg/m^2 higher BMI and a 251 mg/day lower urinary potassium excretion, above and beyond individual-level characteristics. Our results suggest that women may be particularly vulnerable to obesogenic and other negative effects of a socioeconomically disadvantaged neighborhood.

A number of studies have pointed to an association between neighborhood SES and measures of obesity.[6,7,9,33] For example, findings from the Dallas Heart Study, a multiethnic cohort, showed that moving from a higher to a lower SES neighborhood was associated with weight gain.[7] Likewise, among women of the Black Women's Health Study, lower neighborhood SES was associated with weight gain over 10 years.[34] In our multiethnic cohort of NYC adult residents, we too found that living in a low SES neighborhood was associated with measures of obesity such as higher BMI, and the association was only present in women. Prior work has shown individual-level SES to be more strongly associated with obesity in women than in men.[1] However, neighborhood effects on measures of obesity by sex yielded mixed findings.[22-25] For example, among participants of the 1986 American's Changing Lives Study, neighborhood poverty was associated with higher BMI among women but not men.[24] Results from the Multi-Ethnic Study of Atherosclerosis found no association between the social environnment and BMI among women.[25] Further studies exploring associations between the neighborhood environment and obesity, and whether or not these associations vary across different groups, are warranted to better understand the impacts of residing in low SES neighborhoods and to guide the design of more tailored and comprehensive interventions.

Low neighborhood SES was not associated with urinary sodium excretion in men or women. Given the low intraclass correlation coefficient for sodium, indicative of no neighborhood level sodium clustering, our null findings were expected. Our results are in accordance with previous findings from the HFUS cohort showing no association between neighborhood-level poverty and individual-level sodium intake.[19] Similarly, results from the Japan Dietetic Students' Study for Nutrition and Biomarkers Study Group, a Japanese cohort of young women showed no association between neighborhood SES and 24-hour urinary sodium excretion.[35] These results may point to the ubiquity of sodium in the US food supply,[36] such that everyone is exposed regardless of the SES of the neighborhood they live in.

Unlike with sodium, our findings showed significant associations between neighborhood SES and 24-hour urinary potassium excretion, an objective indicator of fruit and vegetable consumption[37] and healthy diet.[21] Our findings are consistent with other studies,[11,12,35,38,39] yet mostly using self-reported fruit and vegetable consumption. For example, findings from the National Health Nutrition and Examination survey showed that higher neighborhood SES was associated with increased fruit and vegetable intake.[11] Likewise, findings from the New York City Community Health Survey have shown that residing in a neighborhood of low vs. high SES was associated with reporting lower fruit and vegetable intake.[12] Prior studies have also linked other neighborhood characteristics, such as neighborhood retail environment, to individual diet quality, including potassium.[38] For example, among participants of the Japan Dietetic Students' Study for Nutrition and Biomarkers Study Group, neighborhood availability of supermarkets was associated with higher urinary potassium excretion.[13]

Previous studies have signaled that the associations between individual-level SES and fruit and vegetable consumption may vary by sex.[37] However, to our knowledge, no prior studies in the US have formally assessed whether the relationship of neighborhood-level SES and diet quality, measured objectively—

such as 24-hour urinary potassium excretion, varies by sex. In our study, we found neighborhood SES to be associated with potassium excretion among women but not men. It has been hypothesized that in general, neighborhood level effects might be stronger for women than men considering women may spend more time in the home and within their neighborhoods.[40]

Finally, our study found that residing in a neighborhood of low vs. high SES was associated with a 0.40 and 0.36 unit higher Na-K ratio in men and women respectively, in unadjusted models. Though limited studies exist, our finding mirrors a study of Japanese women which showed that low vs. high neighborhood SES was associated with higher Na-K ratio, adjusting for only survey year, living status, and region of residence.[35] However, in our study, associations of neighborhood SES with Na-K were no longer significant after we adjusted for covariates.

The current research has few limitations that are worth noting. First, while our study was population based and representative of non-institutionalized NYC adults, our results may not necessarily be extrapolated to other geographical locations given the uniqueness of NYC neighborhoods. We also relied on zip codes to define neighborhoods, though zip codes are commonly utilized to define neighborhoods, smaller geographic units such as census blocks exist but were not accessible. Additionally, 24-hour urine measures reflect sodium and potassium intake during the previous day and may not necessarily be indicative of habitual sodium and potassium consumption. Finally, the HFUS was cross-sectional, thus any observed associations may reflect self-selection of certain individuals into certain neighborhoods rather than the effect of a neighborhood on an individual's health. Despite such limitations, the study possesses noteworthy strengths. Our measure of neighborhood SES was rich as it utilized several SES domains. We were adequately powered to test for interaction by sex, and have found that sex moderated the associations of neighborhood SES with obesity and biomarkers of diet.

Most notably, our outcomes were objectively measured and therefore subject to less measurement error. This is particularly true of our dietary measures, the HFUS study is the only population-based representative study in the US to use the gold-standard of 24-hour urine to measure sodium and potassium intake.

CONCLUSIONS:

In our study, representative of NYC adults, residing in a low vs. high SES neighborhood was associated with measures of obesity and lower urinary potassium excretion among women but not men. This research contributes to the growing body of evidence showing that the neighborhood environment is associated with health. We highlight that the association of SES with obesity and potassium—an objective dietary biomarker—is moderated by sex. Future research related to neighborhood level effects should focus on exploring such sex differences.

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Contributorship Statement

Dr. Elfassy conducted the statistical analyses for this study. Drs. Elfassy and Zeki Al Hazzouri interpreted the data and drafted the manuscript. Drs. Elfassy, Yi, Llabre, Schneiderman, Gellman, Florez, Prado, and Zeki Al Hazzouri contributed to the methodological aspects of this study and were all involved with critical review of the manuscript. The authors have no relevant financial disclosures to report.

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STROBE Statement—checklist of items that should be included in reports of observational studies

	Item No	Recommendation
Line Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract: see title and line 10 of page 5
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found: see abstract on page 5
Introduction		
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported: see introduction on page 7
Objectives	3	State specific objectives, including any prespecified hypotheses: see page 8 line 8
Methods		
Study design	4	Present key elements of study design early in the paper: see page 8 lines 25-50
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection: see page 8 lines 25-50
Participants	6	(*a*) *Cohort study*—Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up: *Case-control study*—Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls NA *Cross-sectional study*—page 10 lines 54-page 11 line 8
		(*b*) *Cohort study*—For matched studies, give matching criteria and number of exposed and unexposed NA *Case-control study*—For matched studies, give matching criteria and the number of controls per case NA
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable: see page 8 line 55 – page 10 line 47
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group: see page 8 line 55 – page 10 line 47
Bias	9	Describe any efforts to address potential sources of bias: page 23 lines 6-11
Study size	10	Explain how the study size was arrived at: page 10 line 54 – page 11 line 8
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why: page 10 lines 17-47
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding: page 11
		(*b*) Describe any methods used to examine subgroups and interactions: page 11 lines 45-50
		(*c*) Explain how missing data were addressed: page 10 lines 54-page 11 line 8
		(*d*) *Cohort study*—If applicable, explain how loss to follow-up was addressed NA *Case-control study*—If applicable, explain how matching of cases and controls was addressed NA *Cross-sectional study*—If applicable, describe analytical methods taking account of sampling strategy: complex survey design-page 11 line 54 – page 12 line 6
		(*e*) Describe any sensitivity analyses : n/a

Results		
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed: page 10 lines 54-page 11 line 8
		(b) Give reasons for non-participation at each stage- page 10 lines 54-page 11 line 8
		(c) Consider use of a flow diagram:
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders: table 1 (page 13) and page 12 and page 13
		(b) Indicate number of participants with missing data for each variable of interest: page 10 lines 54-page 11 line 8
		(c) *Cohort study*—Summarise follow-up time (eg, average and total amount) NA
Outcome data	15*	*Cohort study*—Report numbers of outcome events or summary measures over time NA
		Case-control study—Report numbers in each exposure category, or summary measures of exposure NA
		Cross-sectional study—Report numbers of outcome events or summary measures: NA-outcome is continuous. Beta estimates are reported in the tables (pages 17 and 19)
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included: see tables 3 (page 17) and table 4 (page 19), adjustments are clear
		(*b*) Report category boundaries when continuous variables were categorized-we used tertiles of a factor score, page 10, lines 17-47
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period-NA
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses
Discussion		
Key results	18	Summarise key results with reference to study objectives: Page 20 lines 6-17
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias: page 22, lines 31-49
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence: page 23, lines 17-29
Generalisability	21	Discuss the generalisability (external validity) of the study results: page 23 lines 6-8
Other information		
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based: provided at the end of the manuscript: page 23 line 36-page 24 line 10

BMJ Open

Neighborhood socio-economic status and cross-sectional associations with obesity and urinary biomarkers of diet among New York City adults: The Heart Follow-up Study.

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Neighborhood socio-economic status and cross-sectional associations with obesity and urinary biomarkers of diet among New York City adults: The Heart Follow-up Study.

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ABSTRACT

Objective: To determine whether neighborhood socio-economic status (SES) is associated with body mass index (BMI), waist circumference, and biomarkers of diet (urinary sodium and potassium excretion).

Design: A cross-sectional study.

Setting: The data reported were from the 2010 Heart Follow Up Study, a population based representative survey of 1,645 adults.

Participants: Community dwelling diverse residents of New York City nested within 128 neighborhoods (zip codes).

Primary and secondary outcome measures: BMI (kg/m^2) and waist circumference (inches) were measured during in-home visits, and 24-hour urine was collected to measure biomarkers of diet: sodium (mg/day) and potassium (mg/day).

Results: After adjusting for individual-level characteristics using multilevel linear regressions, low vs. high neighborhood SES tertile was associated with 1.83 kg/m^2 higher body mass index (95% CI: 0.41, 3.98) and 251 mg/day lower potassium excretion (95% CI: -409,-93) among women only, with no associations among men (p-values for neighborhood SES by sex interactions <0.05).

Conclusion: Our results suggest women may be particularly vulnerable to the effects of a socioeconomically disadvantaged neighborhood. Future neighborhood research should explore sex differences, as these can inform tailored interventions.

Trial Registration: This trial is registered at clinicaltrials.gov as NCT01889589.

Strengths and Limitations of this study:

- These data come from the New York City Heart Follow-Up Study, and are population based and representative of the New York City adult population.
- Modeled as tertiles of a factor score, the main exposure of interest, neighborhood socio-economic status, was constructed based on neighborhood levels of education, poverty, unemployment, and safety.
- All outcomes were measured objectively and included measured body mass index, waist circumference, and 24-hour urinary excretion derived measures of sodium, potassium, and sodium to potassium ratio.
- Data were cross-sectional and therefore temporality was not established; additionally the paper does not account for self-selection of certain individuals into certain neighborhoods.

INTRODUCTION:

Poor socio-economic status (SES) has been linked to both higher rates of obesity [1] and poor dietary quality,[2] particularly among women.[1] Mechanisms behind such associations include poverty being associated with unhealthy behaviors[3] and greater exposure to stress-inducing mechanisms.[4] For example, for individuals of low SES, cost is often a barrier to a healthy diet, and therefore, such individuals are more likely to consume less nutritious and more calorie-dense food.[5] However, the extent to which modifying characteristics or behaviors at the individual-level would be successful for achieving better diet quality and lower obesity rates, especially among individuals living in disadvantaged environments, remains unclear.

Beyond individual-level mechanisms, a growing body of research suggests that neighborhood characteristics, such as neighborhood safety and neighborhood SES, may also influence obesity[6-9] and diet quality.[10-14] For example, findings from the landmark Moving To Opportunity study showed that altering the socioeconomic environment by relocating into a higher income neighborhood was associated with a lower prevalence of obesity[15] and improved physical health outcomes in youth girls but not boys.[16] Studies[10-12,17] pointing to a relationship between the neighborhood environment and diet quality have mainly used subjective measures of diet such as healthy eating indices or self-reported fruit and vegetable intake which can be prone to measurement error.[18] To our knowledge, only two previous studies of neighborhood and diet[13,19] have included objectively measured biomarkers of diet quality such as sodium and potassium.[20,21] Furthermore, while it is suggested that neighborhood effects might differ by sex, the relationships between the neighborhood socioeconomic environment with obesity and diet quality are seldom explored by sex and results have been mixed.[16,22-27]

The objective of our analysis was to examine the association between neighborhood SES, obesity, and diet quality using data from the Heart Follow-Up Study (HFUS), a population-[28]based study of New York City (NYC) adult residents by sex. Obesity was ascertained using measured body mass index (BMI) and waist circumference (WC), and diet quality was ascertained using 24-hour urine derived biomarkers of sodium, potassium, and the sodium to potassium (Na-K) ratio.

METHODS

Study design and study sample

The New York City Community Health Survey (CHS) Heart Follow-Up Study (HFUS), is a cross-sectional study conducted in 2010 to assess population-based sodium intake from a representative sample of 1,775 NYC adults ages 18 years or older.[29] Study participants in the HFUS were recruited from the 2010 CHS, a complex survey design telephone parent study of approximately 10,000 New Yorkers conducted by the NYC Health Department.[30] From the 2010 CHS, a total of, 6,342 participants were screened for HFUS eligibility with 5,830 deemed eligible (not pregnant , lactating, or undergoing kidney dialysis). Of eligible participants, a total of 1,775 individuals participated in the HFUS. In brief, study participants in the HFUS answered survey questions and collected urine for a 24-hour period. During a home visit, a trained medical technician took anthropometric measurements, aliquotted the urine, and sent it directly to the research laboratory. All study participants provided informed consent and IRB approval was obtained at both the University of Miami and the NYC Health Department.

Measures of obesity

During in-home visits, HFUS participants' weight and height was recorded without shoes. BMI was calculated as measured weight in kilograms divided by measured height in meters-squared. Waist circumference (WC) was measured in inches as waist girth at the top of the lateral border of the right ilium.

Biomarkers of Diet Quality: urinary sodium and potassium

HFUS participants provided 24-hour urine samples which were sent to the collaborating laboratory at the Mount Sinai Hospital and Medical School and analyzed for sodium, potassium, and creatinine. Sodium and potassium were measured using the ion-selective electrode potentiometric method on the Roche DPP Modular analyzer. Creatinine, used to assess urine completeness,[20] was measured using the Jaffe kinetic colorimetric method on the same analyzer. All laboratory values were normalized to a 24-hour collection period (mg/day). Na-K ratio was defined as the ratio between sodium (mg/day) and potassium (mg/day). Higher sodium, lower potassium, and higher Na-K ratio are indicative of worse diet quality.[20,21]

Other individual-level measures

Through survey questionnaires, HFUS participants reported their age in age groups (18-24, 25-44, 45-64, or 65+ years), sex, and race/ethnicity (white non-hispanic, black non-hispanic, hispanic, asian, or other). Participants reported family size as the number of individuals per household, and also reported whether their household income from all sources was less than 100%, 100 – 199%, 200 – 299%, 300 – 399%, 400 – 499%, 500 – 599%, or 600% or more of the Federal Poverty Level (FPL). For reference, the FPL in 2010 for a household of four people was $22,050.[31] Participants also reported their educational attainment defined as less than high school (HS), HS graduate, some college, or college graduate or more. Employment status was recorded and defined as employed, unemployed, or not in the labor force. Participants also answered a series of questions about their physical activity which were used to calculate their total minutes of moderate and vigorous physical activity.[32] Participants who reported an average of 150 moderate or 75 vigorous minutes of physical activity per week were considered to have met 2008 physical activity guidelines.[33]

Neighborhood SES

Neighborhoods were defined according to zip codes which were retrieved from participants' addresses. We used factor analysis to create a neighborhood SES factor score using zip code level variables. The principle factor method was used to estimate factor scores, and a loading threshold of 0.3 was set to indicate whether a variable should be retained. The final selected variables included: percentage of households in the neighborhood with income 100% below the FPL, percentage of individuals in the neighborhood who are unemployed, percentage of individuals in the neighborhood with less than a HS education, and percentage of individuals in the neighborhood who report living in an unsafe neighborhood. Neighborhood safety was reported in response to the question of "How safe from crime do you consider your neighborhood to be" with responses including "extremely safe," "quite safe," "slightly safe," or "not safe at all"; answers were then dichotomized into two categories: an unsafe neighborhood ("slightly safe" or "not safe at all" responses) vs. a safe neighborhood ("extremely safe" or "quite safe" responses). We then created tertiles from the neighborhood SES score to further characterize neighborhoods as having low SES (disadvantageous), middle SES, or high SES (advantageous).

Statistical Analyses

Of the original 1775 individuals who provided urine samples, a total of 119 were excluded due to an incomplete or biologically implausible urine sample, defined using the following criteria: total urine volume <500 mL, creatinine <6.05 mmol for men or <3.78 mmol for women, or a participant reporting missing a collection.[20] An additional 11 individuals were excluded due to lack of geographic residence (zip code) information, resulting in a final analytic sample of 1645 individuals.

The data structure of this analysis includes 2 levels: 1645 individuals in level 1 nested within 128 neighborhoods in level 2. We first assessed individual-level characteristics of the sample overall and by sex. We then assessed neighborhood-level characteristics overall and across tertiles of the neighborhood SES score. Next, we estimated mean obesity (BMI and WC) and mean dietary characteristics (sodium, potassium, and Na-K ratio) across tertiles of neighborhood SES score, for women and men separately. All means and proportions were age standardized to the US 2010 population so that they could be compared to national US population.

To determine whether a multilevel model and analyses were appropriate, we calculated intraclass correlation coefficients which calculate for each outcome of interest the percent of total variance that is between neighborhoods. Intraclass correlations were 4.4%, 3.6%, 0.17%, 6.6%, and 8.0% respectively for BMI, WC, sodium, potassium, and Na-K ratio. Though the ICC's are of relatively small magnitude, we were uniquely interested in the associations of neighborhood level SES with anthropometrics and diet quality; and thus for all outcomes but sodium a multilevel model could be justified.[28] We then fit multilevel linear regression models to determine whether neighborhood SES score (as tertiles) was associated with each of BMI, WC, sodium, potassium, and Na-K ratio. We tested for effect modification by sex. Models were adjusted for individual level age, race/ethnicity, education, poverty, employment status, physical activity (for BMI and WC models), and BMI (for sodium, potassium, and Na-K models). Data were analyzed in 2016 with survey weights and design variables using SUDAAN (version 10.0; Research Triangle Institute, Research Triangle Park, North Carolina) and MPLUS (Version 7; Muthen and Muthen 1998-2012).

RESULTS

Approximately 13.3% of the sample was 18-24 years of age, 44% were age 25-44 years, 28% were age 45-64 years, and 15% were 65 years or older (Table 1). A total of 39% of the population was non-

Hispanic White, 23% was non-Hispanic Black, 24% was Hispanic, and 10% was Asian. Approximately 21% had less than a HS education, 48% were below 200% of the FPL, and 10% were unemployed. A total of 62.1% of the population met 2008 physical activity guidelines. Compared with men, women were more likely to have less than a HS education and be in poverty, and less likely to be employed.

Table 1. Individual-level characteristics of the study sample, overall and by sex.

	Overall (N=1645)		**Men (n=689)**		**Women (n=956)**	
	%	SE	%	SE	%	SE
Characteristic						
Age group						
18-24	13.3	1.6	14.0	2.4	12.6	2.3
25-44	43.5	2.0	45.4	3.1	41.8	2.7
45-64	27.9	1.6	27.7	2.4	28.0	2.2
65+	15.4	1.2	12.9	1.6	17.5	1.8
Race/Ethnicity						
White	39.0	1.7	45.8	2.6	**33.5****	**2.3**
Black	23.4	1.5	21.9	2.2	24.4	2.2
Hispanic	23.6	1.6	16.9	2.0	**29.3****	**2.4**
Asian	10.3	1.4	11.4	2.3	9.4	1.6
Other	3.7	1.4	4.0	1.3	3.5	1.1
Less than HS Education						
< HS	21.3	1.7	17.6	2.4	**24.5***	**2.5**
HS	27.0	1.8	27.6	2.7	26.7	2.4
Some college	22.0	1.5	23.4	2.4	20.7	2.0
College grad	29.6	1.5	31.3	2.4	28.1	2.0
Poverty						
< 200% FPL	48.1	1.9	41.9	2.9	**53.0****	**2.6**
≥200% FPL	45.9	1.8	54.0	2.7	**39.2****	**2.4**
Don't know/Refused	6.0	1.1	4.1	1.2	7.7	1.9
Employment						
Employed	56.7	1.8	62.6	2.3	**51.2****	**2.6**
Unemployed	10.4	1.2	10.8	1.6	10.1	1.6
Not in labor force	32.9	1.6	26.6	1.9	**38.7****	**2.4**
Meets 2008 Physical Activity guidelines	62.1	1.9	65.3	2.6	58.9	2.7

[a] Estimates are age standardized to the US 2000 population.

Abbreviations: FPL: federal poverty level; HS: high school; SE: standard error.

Boldface indicates statistical significant differences comparing men with women (** *P*<0.01, **P*<0.05)

The proportion of households with income <100% of the FPL and the proportion of individuals reporting living in an unsafe neighborhood was highest (38% and 56% respectively) in the lowest neighborhood SES score tertile and lowest in the highest neighborhood SES tertile (6% and 10% respectively), data not shown. Likewise, the proportion of individuals who were unemployed or with less than a HS education was highest (12% and 27% respectively) in the lowest neighborhood SES tertile and lowest in the highest neighborhood SES tertile (6% and 7% respectively).

Mean 24-hour urinary sodium excretion was 3240 mg/day and did not differ significantly by neighborhood tertile in men or women (Table 2). Among men, those living in a low vs. high SES neighborhoods had significantly lower mean urinary potassium excretion (2131 vs. 2404 mg, $p<0.01$), and higher mean Na-K ratio (1.92 vs. 1.61, $P=0.01$). Among women, those living in a low vs. high SES neighborhood had higher mean BMI (29.3 vs. 26.1 kg/m^2, $p<0.01$), higher mean WC (36.4 vs. 32.9 inches, $p<0.01$), and lower mean urinary potassium excretion (1911 vs. 2238, $p<0.01$). Similarly, women living in middle vs. high SES neighborhoods also had significantly higher mean BMI (28.3 vs. 26.1 kg/m^2, $p<0.01$), higher mean WC (35.8 vs. 32.9 inches, $p<0.01$), and lower mean urinary potassium excretion (1890 vs. 2238, $p<0.01$).

Table 2. Mean obesity and dietary characteristics overall and across tertiles of neighborhood SES score, by sex [a]

	Overall		Men						Women					
			Tertile of Neighborhood SES Score						**Tertile of Neighborhood SES Score**					
			Low (n=216)		Middle (n=258)		High (n=215)		Low (n=422)		Middle (n=304)		High (n=230)	
	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
BMI (kg/m2)	28.2	0.3	28.6	0.5	28.6	0.8	27.3	27.3	**29.3****	**0.5**	**28.3****	**0.5**	26.1	0.5
Waist Circumference (inches)	36.3	0.2	37.6	0.5	37.6	0.7	36.9	0.5	**36.4****	**0.4**	**35.8****	**0.5**	32.9	0.4
Sodium (mg/day)	3,240	58	2,699	159	3,734	134	3,377	159	2,961	106	2,865	108	3,013	150
Potassium (mg/day)	2,182	38	**2,131***	**87**	2,667	135	2,404	92	**1,911****	**63**	**1,890****	61	2,238	95
Na-K Ratio	1.68	0.03	**1.92***	**0.08**	1.63	0.08	1.61	0.10	1.73	0.07	1.70	0.08	1.52	0.09

[a] Estimates are age standardized to the US 2000 population.

Abbreviations: Na-KSE: standard error; SES: socio-economic status

Boldface indicates statistical significant differences when compared to high neighborhood SES using T-tests (** *P*<0.01, **P*<0.05)

In unadjusted and fully adjusted models, neighborhood SES by sex interactions were significant for outcomes of WC (p<0.05) and potassium (p<0.05). Consequently, all models were stratified by sex. Among men, results from unadjusted and fully adjusted multilevel models showed that neighborhood SES was not associated with individual-level BMI or WC (Table 3). Among women, in unadjusted models, living in a low vs. high and middle vs. high neighborhood SES was significantly associated with 3.60 kg/m^2 [95% Confidence interval (CI): 2.00, 5.19] and 2.21 kg/m^2 (95% CI: 1.00, 3.43) higher BMI; *P* for trend < 0.05. Likewise, living in a low vs. high and middle vs. high neighborhood SES was significantly associated with 2.94 inches (95% CI: 0.80, 5.09) and 2.00 inches (95% CI: 0.46, 3.58) larger WC; *P* for trend < 0.05. In fully adjusted models, living in a low vs. high or middle vs. high SES neighborhood remained associated with 2.19 kg/m^2 (95% CI: 0.41, 3.98) and 1.83 kg/m^2 (95% CI: 0.34, 3.31) higher BMI; *P* for trend < 0.05. Living in a middle vs. high neighborhood SES remained significantly associated with 1.86 inches (95% CI: 0.22, 3.50) larger WC.

Table 3. Associations of tertiles of neighborhood SES score with BMI and waist circumference, by sex.

	Men				Women			
	BMI (kg/m^2)		Waist Circumference (inches)		BMI (kg/m^2)		Waist Circumference (inches)	
	Beta	95% CI	Beta	95% CI	Beta	95% CI	Beta	95% CI
Model 1 [ab]								
Neighborhood SES								
Low	1.17	-0.39, 2.74	0.19	-1.42, 1.81	**3.60****	**2.00, 5.19**	**2.94***	**0.80, 5.09**
Middle	1.12	-1.69, 3.93	0.18	-1.77, 2.13	**2.21****	**1.00, 3.43**	**2.00***	**0.46, 3.58**
High	Ref		Ref		Ref		Ref	
Model 2 [ab]								
Neighborhood SES								
Low	0.92	-0.63, 2.47	0.55	-1.24, 2.33	**2.37****	**0.84, 3.89**	**2.21***	**0.19, 4.24**
Middle	1.00	-1.47, 3.47	0.35	-1.52, 2.23	**1.79****	**0.49, 3.10**	**1.83***	**0.27, 3.39**
High	Ref		Ref		Ref		Ref	
Model 3								
Neighborhood SES								
Low	0.62	-1.11, 2.35	0.18	-1.74, 2.09	**2.25****	**0.70, 3.80**	**2.07***	**0.01, 4.14**
Middle	0.85	-1.56, 3.25	0.29	-1.57, 2.14	**1.65***	**0.36, 2.94**	**1.69***	**0.05, 3.33**
High	Ref		Ref		Ref		Ref	
Model 4 [a]								
Neighborhood SES								
Low	0.59	-1.06, 2.23	0.17	-1.66, 1.99	**2.19***	**0.41, 3.98**	2.12	-0.11, 4.34
Middle	1.07	-1.33, 3.48	0.46	-1.39, 2.31	**1.83***	**0.34, 3.31**	**1.86***	**0.22, 3.50**
High	Ref		Ref		Ref		Ref	

[a] Indicates a significant trend for BMI among women, *P*< 0.05; [b] Indicates a significant trend for waist circumference among women, *P*< 0.05

Model 1 is unadjusted; model 2 is adjusted for individual-level age, and race/ethnicity; Model 3 is additionally adjusted for individual-level education, poverty, and employment status; model 4 is additionally adjusted for physical activity.

Abbreviations: CI: confidence interval; SES: socio-economic status.

Boldface indicates statistical significance (** *P*<0.01; * *P*<0.05)

Among men, living in a low vs. high SES neighborhood was significantly associated with 403 mg/day lower potassium excretion (95% CI: -628, -178) and 0.40 (95% CI: 0.13, 0.66) unit higher Na-K ratio in unadjusted models only; *P* for trend was significant (*P* < 0.05) for both outcomes in Model 1 (Table 4). From fully adjusted multilevel models among men, middle vs. high SES neighborhood was significantly associated with 313 mg higher potassium excretion (95% CI: 9, 618); all other associations among men were null. Among women, from unadjusted multilevel models, living in a low vs. high or middle vs. high SES neighborhood was significantly associated with 426 mg/day (95% CI: -614, -238) and 425 mg/day (95% CI: -604, -245) lower potassium excretion; *P* for trend < 0.05. Likewise low vs. high SES neighborhood was associated with 0.36 (95% CI: 0.16, 0.56) units higher Na-K ratio among women; *P* for trend < 0.05. From fully adjusted models among women, living in a low vs. high or middle vs. high SES neighborhood remained significantly associated with 251 mg/day (95% CI: -409, -93) and 330 mg/day (95% CI: -501, -159) lower potassium excretion; *P* for trend < 0.05.

Table 4. Associations of tertiles of neighborhood SES score with urinary sodium, potassium, and Na-K excretion by sex.

	Men						Women					
	Sodium (mg/day)		Potassium (mg/day)		Sodium to Potassium Ratio		Sodium (mg/day)		Potassium (mg/day)		Sodium to Potassium Ratio	
	Beta	95% CI	Beta	95% CI	Beta	95% CI	Beta	95% CI	Beta	95% CI	Beta	95% CI
Model 1 [abcd]												
Neighborhood SES												
Low	12	-426, 451	**-403****	**-628, -178**	**0.40****	**0.13, 0.66**	42	-217, 301	**-426****	**-614, -238**	**0.36****	**0.16, 0.56**
Middle	64	-410, 538	-14	-235, 208	0.13	-0.10, 0.36	-61	-318, 195	**-425****	**-604, -245**	0.27	0.05, 0.49
High	Ref		Ref		Ref		Ref		Ref		Ref	
Model 2 [b]												
Neighborhood SES												
Low	-2	-512, 508	-101	-236, 123	0.11	-0.13, 0.34	-116	-362, 129	**-266****	**-446, -86**	0.09	-0.08, 0.27
Middle	77	-335, 489	231	-105, 513	-0.08	-0.33, 0.17	-156	-416, 103	**-331****	**-509, -152**	0.13	-0.04, 0.30
High	Ref		Ref		Ref		Ref		Ref		Ref	
Model 3 [b]												
Neighborhood SES												
Low	-21	-591, 550	31	-195, 257	0.05	-0.19, 0.29	-130	-404, 144	**-244****	**-415, -73**	0.04	-0.13, 0.21
Middle	80	-325, 486	319	-13, 651	-0.11	-0.34, 0.12	-183	-452, 87	**-328****	**-507, -148**	0.10	-0.07, 0.26
High	Ref		Ref		Ref		Ref		Ref		Ref	
Model 4 [b]												
Neighborhood SES												
Low	78	-478, 545	47	-180, 274	0.04	-0.19, 0.28	-205	-475, 64	**-251****	**-409, -93**	-0.01	-0.19, 0.16
Middle	168	-347, 1775	**313***	**9, 618**	-0.12	-0.35, 0.11	-227	-478, 24	**-330****	**-501, -159**	0.06	-0.11, 0.24
High	Ref		Ref		Ref		Ref		Ref		Ref	

[a] Indicates a significant trend for potassium among men, $P<0.05$; [b] Indicates a significant trend for potassium among women, $P<0.05$
[c] Indicates a significant trend for Na-K among men, $P<0.05$; [d] Indicates a significant trend for Na-K among women, $P<0.05$
Model 1 is unadjusted; model 2 is adjusted for individual-level age, and race/ethnicity; Model 3 is additionally adjusted for individual-level education, poverty, and employment status; model 4 is additionally adjusted for physical activity.
Abbreviations: CI: confidence interval; Na-K: sodium to potassium ratio; SES: socio-economic status.
Boldface indicates statistical significance (** $P<0.01$; * $P<0.05$)

DISCUSSION

Findings from this study suggest strong associations between lower neighborhood SES and higher BMI and WC, and lower urinary potassium excretion among women but not men. Among women, residing in a low vs. high SES neighborhood was associated with a 2.19 kg/m^2 higher BMI and a 251 mg/day lower urinary potassium excretion, above and beyond individual-level characteristics. Our results suggest that women may be particularly vulnerable to obesogenic and other negative effects of a socioeconomically disadvantaged neighborhood.

A number of studies have pointed to an association between neighborhood SES and measures of obesity.[6,7,9,34] For example, findings from the Dallas Heart Study, a multiethnic cohort, showed that moving from a higher to a lower SES neighborhood was associated with weight gain.[7] Likewise, among women of the Black Women's Health Study, lower neighborhood SES was associated with weight gain over 10 years.[35] Though neither of these studies focused on differences by sex. In our multiethnic cohort of NYC adult residents—using a more comprehensive measure of neighborhood SES, we too found that living in a low SES neighborhood was associated with measures of obesity such as higher BMI, and the association was only present in women. Prior work has shown individual-level SES to be more strongly associated with obesity in women than in men.[1] However, neighborhood effects on measures of obesity by sex yielded mixed findings.[22-25] For example, among participants of the 1986 American's Changing Lives Study, neighborhood poverty was associated with higher BMI among women but not men.[24] Results from the Multi-Ethnic Study of Atherosclerosis found no association between the social environment and BMI among women.[25] Further studies exploring associations between the neighborhood environment and obesity, and whether or not these associations vary across different groups, are warranted to better understand the impacts of residing in low SES neighborhoods and to guide the design of more tailored and comprehensive interventions.

Low neighborhood SES was not associated with urinary sodium excretion in men or women. Given the low intraclass correlation coefficient for sodium, indicative of no neighborhood level sodium clustering, our null findings were expected. Our results are in accordance with previous findings from the HFUS cohort showing no association between neighborhood-level poverty and individual-level sodium intake.[19] Similarly, results from the Japan Dietetic Students' Study for Nutrition and Biomarkers Study Group, a Japanese cohort of young women showed no association between neighborhood SES and 24-hour urinary sodium excretion.[36] These results may point to the ubiquity of sodium in the US food supply,[37] such that everyone is exposed regardless of the SES of the neighborhood they live in.

Unlike with sodium, our findings showed significant associations between neighborhood SES and 24-hour urinary potassium excretion, an objective indicator of fruit and vegetable consumption[38] and healthy diet.[21] As potassium is an important nutrient that helps lower blood pressure,[39] the strength of these results cannot be underscored; a 251 mg/day difference is substantial—especially on a population wide basis—considering recommended intake should be 4700 mg/day.[40] Importantly, our findings are consistent with other studies,[11,12,36,41,42] yet mostly using self-reported fruit and vegetable consumption. For example, findings from the National Health Nutrition and Examination survey showed that higher neighborhood SES was associated with increased fruit and vegetable intake.[11] Likewise, findings from the New York City Community Health Survey have shown that residing in a neighborhood of low vs. high SES was associated with reporting lower fruit and vegetable intake.[12] Prior studies have also linked other neighborhood characteristics, such as neighborhood retail environment, to individual diet quality, including potassium.[41] For example, among participants of the Japan Dietetic Students' Study for Nutrition and Biomarkers Study Group, neighborhood availability of supermarkets was associated with higher urinary potassium excretion.[13] Finally, previous HFUS findings showed that neighborhood poverty was not associated with 24 hour urinary excretion of potassium.[19] However, this study used different methods which likely accounted for the discrepant findings. For example, the current analysis includes more neighborhood level units (i.e. 128 vs. 42 neighborhoods), a different neighborhood SES construct comprised of multiple dimensions of SES rather than just poverty, and sex stratified models. Had we used overall rather than sex-stratified models, associations for potassium would have been null.

Previous studies have signaled that the associations between individual-level SES and fruit and vegetable consumption may vary by sex.[38] However, to our knowledge, no prior studies in the US have formally assessed whether the relationship of neighborhood-level SES and diet quality, measured objectively—such as 24-hour urinary potassium excretion, varies by sex. In our study, we found neighborhood SES to be associated with potassium excretion among women but not men. It has been hypothesized that in general, neighborhood level effects might be stronger for women than men considering women may spend more time in the home and within their neighborhoods.[43]

Finally, our study found that residing in a neighborhood of low vs. high SES was associated with a 0.40 and 0.36 unit higher Na-K ratio in men and women respectively, in unadjusted models. Individuals consuming USDA recommendations[40] for sodium (< 2300 mg/day) and potassium (≥4700 mg/day) would have an Na-K ratio of 0.49. Thus differences in the order of 0.4 in magnitude are substantial; though these findings were not significant in adjusted models. Though limited studies exist, our findings are somewhat consistent with a study of Japanese women showing that low vs. high neighborhood SES was associated with higher Na-K ratio, adjusting for only survey year, living status, and region of residence.[36]

The current research has a few limitations that are worth noting. First, while our study was population based and representative of non-institutionalized NYC adults, our results may not necessarily be extrapolated to other geographical locations given the uniqueness of NYC neighborhoods. Further, we relied on zip codes to define neighborhoods; zip codes may encompass a more heterogeneous SES composition and therefore introduce heterogeneity into the measure. Despite this, we believe the use of zip code is appropriate for the following reasons: 1) NYC is a densely populated area and so zip codes encompass much smaller geographical bounds than in other locations, and 2) any heterogeneity introduced in our measure would likely bias results towards the null. Yet, we still found substantial and strong neighborhood level effects. Additionally, 24-hour urine measures reflect sodium and potassium intake during the previous day and may not necessarily be indicative of habitual sodium and potassium consumption. Further though we were adequately powered to test for interaction by sex, stratification by sex resulted in smaller sample sizes and notably limited the precision our estimates—particularly for our dietary factors of sodium and potassium which are highly variable. Finally, the HFUS was cross-sectional, thus any observed associations may reflect self-selection of certain individuals into certain neighborhoods rather than the effect of a neighborhood on an individual's health. Despite such limitations, the study possesses noteworthy strengths. Our measure of neighborhood SES was rich as it utilized several SES domains. Most notably, our outcomes were objectively measured and therefore subject to less measurement error. This is particularly true of our dietary measures, the HFUS study is the first population-based representative study in the US to use the gold-standard of 24-hour urine to measure sodium and potassium intake.

CONCLUSIONS:

In our study, representative of NYC adults, residing in a low vs. high SES neighborhood was associated with measures of obesity and lower urinary potassium excretion among women but not men. This research contributes to the growing body of evidence showing that the neighborhood environment is associated with health. We highlight that the association of SES with obesity and potassium—an objective dietary biomarker—is moderated by sex. Future research related to neighborhood level effects should focus on exploring such sex differences.

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Contributor Statement

Dr. Elfassy conducted the statistical analyses for this study. Drs. Elfassy and Zeki Al Hazzouri interpreted the data and drafted the manuscript. Drs. Elfassy, Yi, Llabre, Schneiderman, Gellman, Florez, Prado, and Zeki Al Hazzouri contributed to the methodological aspects of this study and were all involved with critical review of the manuscript. The authors have no relevant financial disclosures to report.

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STROBE Statement—checklist of items that should be included in reports of observational studies

	Item No	Recommendation
Line Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract: see title and line 10 of page 5
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found: see abstract on page 5
Introduction		
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported: see introduction on page 7
Objectives	3	State specific objectives, including any prespecified hypotheses: see page 8 line 8
Methods		
Study design	4	Present key elements of study design early in the paper: see page 8 lines 25-50
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection: see page 8 lines 25-50
Participants	6	(*a*) *Cohort study*—Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up: *Case-control study*—Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls NA *Cross-sectional study*—page 10 lines 54-page 11 line 8
		(*b*) *Cohort study*—For matched studies, give matching criteria and number of exposed and unexposed NA *Case-control study*—For matched studies, give matching criteria and the number of controls per case NA
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable: see page 8 line 55 – page 10 line 47
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group: see page 8 line 55 – page 10 line 47
Bias	9	Describe any efforts to address potential sources of bias: page 23 lines 6-11
Study size	10	Explain how the study size was arrived at: page 10 line 54 – page 11 line 8
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why: page 10 lines 17-47
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding: page 11
		(*b*) Describe any methods used to examine subgroups and interactions: page 11 lines 45-50
		(*c*) Explain how missing data were addressed: page 10 lines 54-page 11 line 8
		(*d*) *Cohort study*—If applicable, explain how loss to follow-up was addressed NA *Case-control study*—If applicable, explain how matching of cases and controls was addressed NA *Cross-sectional study*—If applicable, describe analytical methods taking account of sampling strategy: complex survey design-page 11 line 54 – page 12 line 6
		(*e*) Describe any sensitivity analyses : n/a

Results		
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed: page 10 lines 54-page 11 line 8
		(b) Give reasons for non-participation at each stage- page 10 lines 54-page 11 line 8
		(c) Consider use of a flow diagram:
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders: table 1 (page 13) and page 12 and page 13
		(b) Indicate number of participants with missing data for each variable of interest: page 10 lines 54-page 11 line 8
		(c) *Cohort study*—Summarise follow-up time (eg, average and total amount) NA
Outcome data	15*	*Cohort study*—Report numbers of outcome events or summary measures over time NA
		Case-control study—Report numbers in each exposure category, or summary measures of exposure NA
		Cross-sectional study—Report numbers of outcome events or summary measures: NA-outcome is continuous. Beta estimates are reported in the tables (pages 17 and 19)
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included: see tables 3 (page 17) and table 4 (page 19), adjustments are clear
		(*b*) Report category boundaries when continuous variables were categorized-we used tertiles of a factor score, page 10, lines 17-47
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period-NA
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses
Discussion		
Key results	18	Summarise key results with reference to study objectives: Page 20 lines 6-17
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias: page 22, lines 31-49
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence: page 23, lines 17-29
Generalisability	21	Discuss the generalisability (external validity) of the study results: page 23 lines 6-8
Other information		
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based: provided at the end of the manuscript: page 23 line 36-page 24 line 10

BMJ Open

Neighborhood socio-economic status and cross-sectional associations with obesity and urinary biomarkers of diet among New York City adults: The Heart Follow-up Study.

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Neighborhood socio-economic status and cross-sectional associations with obesity and urinary biomarkers of diet among New York City adults: The Heart Follow-up Study.

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ABSTRACT

Objective: To determine whether neighborhood socio-economic status (SES) is associated with body mass index (BMI), waist circumference, and biomarkers of diet (urinary sodium and potassium excretion).

Design: A cross-sectional study.

Setting: The data reported were from the 2010 Heart Follow Up Study, a population based representative survey of 1,645 adults.

Participants: Community dwelling diverse residents of New York City nested within 128 neighborhoods (zip codes).

Primary and secondary outcome measures: BMI (kg/m^2) and waist circumference (inches) were measured during in-home visits, and 24-hour urine was collected to measure biomarkers of diet: sodium (mg/day) and potassium (mg/day), with high sodium and low potassium indicative of worse diet quality.

Results: After adjusting for individual-level characteristics using multilevel linear regressions, low vs. high neighborhood SES tertile was associated with 1.83 kg/m^2 higher body mass index (95% CI: 0.41, 3.98) and 251 mg/day lower potassium excretion (95% CI: -409,-93) among women only, with no associations among men (p-values for neighborhood SES by sex interactions <0.05).

Conclusion: Our results suggest women may be particularly vulnerable to the effects of a socioeconomically disadvantaged neighborhood. Future neighborhood research should explore sex differences, as these can inform tailored interventions.

Trial Registration: This trial is registered at clinicaltrials.gov as NCT01889589.

Strengths and Limitations of this study:

- These data come from the New York City Heart Follow-Up Study, and are population based and representative of the New York City adult population.
- Modeled as tertiles of a factor score, the main exposure of interest, neighborhood socio-economic status, was constructed based on neighborhood levels of education, poverty, unemployment, and safety.
- All outcomes were measured objectively and included measured body mass index, waist circumference, and 24-hour urinary excretion derived measures of sodium, potassium, and sodium to potassium ratio.
- Data were cross-sectional and therefore temporality was not established; additionally the paper does not account for self-selection of certain individuals into certain neighborhoods.

INTRODUCTION:

Poor socio-economic status (SES) has been linked to both higher rates of obesity [1] and poor dietary quality,[2] particularly among women.[1] Mechanisms behind such associations include poverty being associated with unhealthy behaviors[3] and greater exposure to stress-inducing mechanisms.[4] For example, for individuals of low SES, cost is often a barrier to a healthy diet, and therefore, such individuals are more likely to consume less nutritious and more calorie-dense food.[5] However, the extent to which modifying characteristics or behaviors at the individual-level would be successful for achieving better diet quality and lower obesity rates, especially among individuals living in disadvantaged environments, remains unclear.

Beyond individual-level mechanisms, a growing body of research suggests that neighborhood characteristics, such as neighborhood safety and neighborhood SES, may also influence obesity[6-9] and diet quality.[10-14] For example, findings from the landmark Moving To Opportunity study showed that altering the socioeconomic environment by relocating into a higher income neighborhood was associated with a lower prevalence of obesity[15] and improved physical health outcomes in youth girls but not boys.[16] Studies[10-12,17] pointing to a relationship between the neighborhood environment and diet quality have mainly used subjective measures of diet such as healthy eating indices or self-reported fruit and vegetable intake which can be prone to measurement error.[18] To our knowledge, only two previous studies of neighborhood and diet[13,19] have included objectively measured biomarkers of diet quality such as sodium and potassium.[20,21] Furthermore, it is suggested that the impact of SES on health might differ by sex, with a stronger association among women. For example, a number of studies have linked poor SES to higher rates of obesity in women only or to a greater extent.[1,22,23] Yet, the relationships between the neighborhood socioeconomic environment with obesity and diet quality are seldom explored by sex and results have been mixed.[16,24-29]

The objective of our analysis was to examine the association between neighborhood SES, obesity, and diet quality using data from the Heart Follow-Up Study (HFUS), a population-[30]based study of New York City (NYC) adult residents by sex. Obesity was ascertained using measured body mass index (BMI) and waist circumference (WC), and diet quality was ascertained using 24-hour urine derived biomarkers of sodium, potassium, and the sodium to potassium (Na-K) ratio.

METHODS

Study design and study sample

The New York City Community Health Survey (CHS) Heart Follow-Up Study (HFUS), is a cross-sectional study conducted in 2010 to assess population-based sodium intake from a representative sample of 1,775 NYC adults ages 18 years or older.[31] Study participants in the HFUS were recruited from the 2010 CHS, a complex survey design telephone parent study of approximately 10,000 New Yorkers conducted by the NYC Health Department.[32] From the 2010 CHS, a total of, 6,342 participants were screened for HFUS eligibility with 5,830 deemed eligible (not pregnant , lactating, or undergoing kidney dialysis). Of eligible participants, a total of 1,775 individuals participated in the HFUS. In brief, study participants in the HFUS answered survey questions and collected urine for a 24-hour period. During a home visit, a trained medical technician took anthropometric measurements, aliquotted the urine, and sent it directly to the research laboratory. All study participants provided informed consent and IRB approval was obtained at both the University of Miami and the NYC Health Department.

Measures of obesity

For obesity, we considered two outcome measures: BMI as a measure of total fat, and waist circumference (WC), a strong determinant of metabolic disease risk,[33,34] as a measure of central adiposity. During in-home visits, HFUS participants' weight and height was recorded without shoes. BMI was calculated as measured weight in kilograms divided by measured height in meters-squared. WC was measured in inches as waist girth at the top of the lateral border of the right ilium.

Biomarkers of Diet Quality: urinary sodium and potassium

HFUS participants provided 24-hour urine samples which were sent to the collaborating laboratory at the Mount Sinai Hospital and Medical School and analyzed for sodium, potassium, and creatinine. Sodium and potassium were measured using the ion-selective electrode potentiometric method on the Roche DPP Modular analyzer. Creatinine, used to assess urine completeness,[20] was measured using the Jaffe kinetic colorimetric method on the same analyzer. All laboratory values were normalized to a 24-hour collection period (mg/day). Na-K ratio was defined as the ratio between sodium (mg/day) and potassium (mg/day). Higher sodium, lower potassium, and higher Na-K ratio are indicative of worse diet quality.[20,21]

Other individual-level measures

Through survey questionnaires, HFUS participants reported their age in age groups (18-24, 25-44, 45-64, or 65+ years), sex, and race/ethnicity (white non-hispanic, black non-hispanic, hispanic, asian, or other). Participants reported family size as the number of individuals per household, and also reported whether their household income from all sources was less than 100%, 100 – 199%, 200 – 299%, 300 – 399%, 400 – 499%, 500 – 599%, or 600% or more of the Federal Poverty Level (FPL). For reference, the FPL in 2010 for a household of four people was $22,050.[35] Participants also reported their educational attainment defined as less than high school (HS), HS graduate, some college, or college graduate or more.

Employment status was recorded and defined as employed, unemployed, or not in the labor force. Participants also answered a series of questions about their physical activity which were used to calculate their total minutes of moderate and vigorous physical activity.[36] Participants who reported an average of 150 moderate or 75 vigorous minutes of physical activity per week were considered to have met 2008 physical activity guidelines.[37] Participants were also asked to rate the safety of their neighborhoods. Neighborhood safety was reported in response to the question of "How safe from crime do you consider your neighborhood to be" with responses including "extremely safe," "quite safe," "slightly safe," or "not safe at all"; answers were then dichotomized into two categories: an unsafe neighborhood ("slightly safe" or "not safe at all" responses) vs. a safe neighborhood ("extremely safe" or "quite safe" responses).

Neighborhood SES

Neighborhoods were defined according to zip codes which were retrieved from participants' addresses. Individual level responses for household poverty level, educational attainment, employment, and perceived neighborhood safety (all defined above) were aggregated by neighborhood to create neighborhood level variables for: proportion of households in the neighborhood with income 100% below the FPL, proportion of individuals in the neighborhood who are unemployed, proportion of individuals in the neighborhood with less than a HS education, and proportion of individuals in the neighborhood who report living in an unsafe neighborhood. All neighborhood level variables were expressed as a proportion with a potential range of 0% to 100%. Then, using the principle factor method, we created a neighborhood SES factor score using these neighborhood level variables; all neighborhood level variables met a loading threshold criteria of 0.3. Finally, we created tertiles from the neighborhood SES score to further characterize neighborhoods as having low SES (disadvantageous), middle SES, or high SES (advantageous).

Statistical Analyses

Of the original 1775 individuals who provided urine samples, a total of 119 were excluded due to an incomplete or biologically implausible urine sample, defined using the following criteria: total urine volume <500 mL, creatinine <6.05 mmol for men or <3.78 mmol for women, or a participant reporting missing a collection.[20] An additional 11 individuals were excluded due to lack of geographic residence (zip code) information, resulting in a final analytic sample of 1645 individuals.

The data structure of this analysis includes 2 levels: 1645 individuals in level 1 nested within 128 neighborhoods in level 2. We first assessed individual-level characteristics of the sample overall and by sex. We then assessed neighborhood-level characteristics overall and across tertiles of the neighborhood SES score. Next, we estimated mean obesity (BMI and WC) and mean dietary characteristics (sodium, potassium, and Na-K ratio) across tertiles of neighborhood SES score, for women and men separately. All means and proportions were age standardized to the US 2010 population so that they could be compared to national US population.

To determine whether a multilevel model and analyses were appropriate, we calculated intraclass correlation coefficients which calculate for each outcome of interest the percent of total variance that is between neighborhoods. Intraclass correlations were 4.4%, 3.6%, 0.17%, 6.6%, and 8.0% respectively for BMI, WC, sodium, potassium, and Na-K ratio. Though the ICC's are of relatively small magnitude, we were uniquely interested in the associations of neighborhood level SES with anthropometrics and diet quality; and thus for all outcomes but sodium a multilevel model could be justified.[30] We then fit multilevel linear regression models to determine whether neighborhood SES score (as tertiles) was associated with each of BMI, WC, sodium, potassium, and Na-K ratio. We tested for effect modification by sex. Models were adjusted for individual level age, race/ethnicity, education, poverty, employment status, physical activity (for BMI and WC models), and BMI (for sodium, potassium, and Na-K models). Data were analyzed in 2016 with survey weights and design variables using SUDAAN (version 10.0; Research Triangle Institute, Research Triangle Park, North Carolina) and MPLUS (Version 7; Muthen and Muthen 1998-2012).

RESULTS

Approximately 13.3% of the sample was 18-24 years of age, 44% were age 25-44 years, 28% were age 45-64 years, and 15% were 65 years or older (Table 1). A total of 39% of the population was non-Hispanic White, 23% was non-Hispanic Black, 24% was Hispanic, and 10% was Asian. Approximately 21% had less than a HS education, 48% were below 200% of the FPL, and 10% were unemployed. A total of 62.1% of the population met 2008 physical activity guidelines. Compared with men, women were more likely to have less than a HS education and be in poverty, and less likely to be employed.

Table 1. Individual-level characteristics of the study sample, overall and by sex.

	Overall (N=1645)		Men (n=689)		Women (n=956)	
	%	SE	%	SE	%	SE
Characteristic						
Age group						
18-24	13.3	1.6	14.0	2.4	12.6	2.3
25-44	43.5	2.0	45.4	3.1	41.8	2.7
45-64	27.9	1.6	27.7	2.4	28.0	2.2
65+	15.4	1.2	12.9	1.6	17.5	1.8
Race/Ethnicity						
White	39.0	1.7	45.8	2.6	**33.5****	**2.3**
Black	23.4	1.5	21.9	2.2	24.4	2.2
Hispanic	23.6	1.6	16.9	2.0	**29.3****	**2.4**
Asian	10.3	1.4	11.4	2.3	9.4	1.6
Other	3.7	1.4	4.0	1.3	3.5	1.1
Less than HS Education						
< HS	21.3	1.7	17.6	2.4	**24.5***	**2.5**
HS	27.0	1.8	27.6	2.7	26.7	2.4
Some college	22.0	1.5	23.4	2.4	20.7	2.0
College grad	29.6	1.5	31.3	2.4	28.1	2.0
Poverty						
< 200% FPL	48.1	1.9	41.9	2.9	**53.0****	**2.6**
≥200% FPL	45.9	1.8	54.0	2.7	**39.2****	**2.4**
Don't know/Refused	6.0	1.1	4.1	1.2	7.7	1.9
Employment						
Employed	56.7	1.8	62.6	2.3	**51.2****	**2.6**
Unemployed	10.4	1.2	10.8	1.6	10.1	1.6
Not in labor force	32.9	1.6	26.6	1.9	**38.7****	**2.4**
Meets 2008 Physical Activity guidelines	62.1	1.9	65.3	2.6	58.9	2.7

[a] Estimates are age standardized to the US 2000 population.
Abbreviations: FPL: federal poverty level; HS: high school; SE: standard error.
Boldface indicates statistical significant differences comparing men with women (** *P*<0.01, **P*<0.05)

The proportion of households with income <100% of the FPL and the proportion of individuals reporting living in an unsafe neighborhood was highest (38% and 56% respectively) in the lowest neighborhood SES score tertile and lowest in the highest neighborhood SES tertile (6% and 10% respectively), data not shown. Likewise, the proportion of individuals who were unemployed or with less than a HS education was highest (12% and 27% respectively) in the lowest neighborhood SES tertile and lowest in the highest neighborhood SES tertile (6% and 7% respectively).

Mean 24-hour urinary sodium excretion was 3,240 mg/day and did not differ significantly by neighborhood tertile in men or women (Table 2). Among men, those living in a low vs. high SES neighborhoods had significantly lower mean urinary potassium excretion (2,131 vs. 2,404 mg, p<0.01), and higher mean Na-K ratio (1.92 vs. 1.61, P=0.01). Among women, those living in a low vs. high SES neighborhood had higher mean BMI (29.3 vs. 26.1 kg/m^2, p<0.01), higher mean WC (36.4 vs. 32.9 inches, p<0.01), and lower mean urinary potassium excretion (1,911 vs. 2,238, p<0.01). Similarly, women living in middle vs. high SES neighborhoods also had significantly higher mean BMI (28.3 vs. 26.1 kg/m^2, p<0.01), higher mean WC (35.8 vs. 32.9 inches, p<0.01), and lower mean urinary potassium excretion (1,890 vs. 2,238, p<0.01).

Table 2. Mean obesity and dietary characteristics overall and across tertiles of neighborhood SES score, by sex [a]

	Overall		Men						Women					
			Tertile of Neighborhood SES Score						Tertile of Neighborhood SES Score					
			Low (n=216)		Middle (n=258)		High (n=215)		Low (n=422)		Middle (n=304)		High (n=230)	
	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
BMI (kg/m2)	28.2	0.3	28.6	0.5	28.6	0.8	27.3	27.3	**29.3****	**0.5**	**28.3****	**0.5**	26.1	0.5
Waist Circumference (inches)	36.3	0.2	37.6	0.5	37.6	0.7	36.9	0.5	**36.4****	**0.4**	**35.8****	**0.5**	32.9	0.4
Sodium (mg/day)	3,240	58	2,699	159	3,734	134	3,377	159	2,961	106	2,865	108	3,013	150
Potassium (mg/day)	2,182	38	**2,131***	**87**	2,667	135	2,404	92	**1,911****	**63**	**1,890****	61	2,238	95
Na-K Ratio	1.68	0.03	**1.92***	**0.08**	1.63	0.08	1.61	0.10	1.73	0.07	1.70	0.08	1.52	0.09

[a] Estimates are age standardized to the US 2000 population.

Abbreviations: Na-KSE: standard error; SES: socio-economic status

Boldface indicates statistical significant differences when compared to high neighborhood SES using T-tests (** *P*<0.01, **P*<0.05)

In unadjusted and fully adjusted models, neighborhood SES by sex interactions were significant for outcomes of WC ($p<0.05$) and potassium ($p<0.05$). Consequently, all models were stratified by sex. Among men, results from unadjusted and fully adjusted multilevel models showed that neighborhood SES was not associated with individual-level BMI or WC (Table 3). Among women, in unadjusted models, living in a low vs. high and middle vs. high neighborhood SES was significantly associated with 3.60 kg/m^2 [95% Confidence interval (CI): 2.00, 5.19] and 2.21 kg/m^2 (95% CI: 1.00, 3.43) higher BMI; *P* for trend < 0.05. Likewise, living in a low vs. high and middle vs. high neighborhood SES was significantly associated with 2.94 inches (95% CI: 0.80, 5.09) and 2.00 inches (95% CI: 0.46, 3.58) larger WC; *P* for trend < 0.05. In fully adjusted models, living in a low vs. high or middle vs. high SES neighborhood remained associated with 2.19 kg/m^2 (95% CI: 0.41, 3.98) and 1.83 kg/m^2 (95% CI: 0.34, 3.31) higher BMI; *P* for trend < 0.05. Living in a middle vs. high neighborhood SES remained significantly associated with 1.86 inches (95% CI: 0.22, 3.50) larger WC.

Table 3. Associations of tertiles of neighborhood SES score with BMI and waist circumference, by sex.

	Men				Women			
	BMI (kg/m^2)		Waist Circumference (inches)		BMI (kg/m^2)		Waist Circumference (inches)	
	Beta	95% CI	Beta	95% CI	Beta	95% CI	Beta	95% CI
Model 1 [ab]								
Neighborhood SES								
Low	1.17	-0.39, 2.74	0.19	-1.42, 1.81	**3.60****	**2.00, 5.19**	**2.94***	**0.80, 5.09**
Middle	1.12	-1.69, 3.93	0.18	-1.77, 2.13	**2.21****	**1.00, 3.43**	**2.00***	**0.46, 3.58**
High	Ref		Ref		Ref		Ref	
Model 2 [ab]								
Neighborhood SES								
Low	0.92	-0.63, 2.47	0.55	-1.24, 2.33	**2.37****	**0.84, 3.89**	**2.21***	**0.19, 4.24**
Middle	1.00	-1.47, 3.47	0.35	-1.52, 2.23	**1.79****	**0.49, 3.10**	**1.83***	**0.27, 3.39**
High	Ref		Ref		Ref		Ref	
Model 3								
Neighborhood SES								
Low	0.62	-1.11, 2.35	0.18	-1.74, 2.09	**2.25****	**0.70, 3.80**	**2.07***	**0.01, 4.14**
Middle	0.85	-1.56, 3.25	0.29	-1.57, 2.14	**1.65***	**0.36, 2.94**	**1.69***	**0.05, 3.33**
High	Ref		Ref		Ref		Ref	
Model 4 [a]								
Neighborhood SES								
Low	0.59	-1.06, 2.23	0.17	-1.66, 1.99	**2.19***	**0.41, 3.98**	2.12	-0.11, 4.34
Middle	1.07	-1.33, 3.48	0.46	-1.39, 2.31	**1.83***	**0.34, 3.31**	**1.86***	**0.22, 3.50**
High	Ref		Ref		Ref		Ref	

[a] Indicates a significant trend for BMI among women, *P*< 0.05; [b] Indicates a significant trend for waist circumference among women, *P*< 0.05
Model 1 is unadjusted; model 2 is adjusted for individual-level age, and race/ethnicity; Model 3 is additionally adjusted for individual-level education, poverty, and employment status; model 4 is additionally adjusted for physical activity.
Abbreviations: CI: confidence interval; SES: socio-economic status.
Boldface indicates statistical significance (** *P*<0.01; * *P*<0.05)

Among men, living in a low vs. high SES neighborhood was significantly associated with 403 mg/day lower potassium excretion (95% CI: -628, -178) and 0.40 (95% CI: 0.13, 0.66) unit higher Na-K ratio in unadjusted models only; *P* for trend was significant (*P* < 0.05) for both outcomes in Model 1 (Table 4). From fully adjusted multilevel models among men, middle vs. high SES neighborhood was significantly associated with 313 mg higher potassium excretion (95% CI: 9, 618); all other associations among men were null. Among women, from unadjusted multilevel models, living in a low vs. high or middle vs. high SES neighborhood was significantly associated with 426 mg/day (95% CI: -614, -238) and 425 mg/day (95% CI: -604, -245) lower potassium excretion; *P* for trend < 0.05. Likewise low vs. high SES neighborhood was associated with 0.36 (95% CI: 0.16, 0.56) units higher Na-K ratio among women; *P* for trend < 0.05. From fully adjusted models among women, living in a low vs. high or middle vs. high SES neighborhood remained significantly associated with 251 mg/day (95% CI: -409, -93) and 330 mg/day (95% CI: -501, -159) lower potassium excretion; *P* for trend < 0.05.

Table 4. Associations of tertiles of neighborhood SES score with urinary sodium, potassium, and Na-K excretion by sex.

	Men						Women					
	Sodium (mg/day)		Potassium (mg/day)		Sodium to Potassium Ratio		Sodium (mg/day)		Potassium (mg/day)		Sodium to Potassium Ratio	
	Beta	95% CI	Beta	95% CI	Beta	95% CI	Beta	95% CI	Beta	95% CI	Beta	95% CI
Model 1 [abcd]												
Neighborhood SES												
Low	12	-426, 451	**-403****	**-628, -178**	**0.40****	**0.13, 0.66**	42	-217, 301	**-420****	**-614, -238**	**0.36****	**0.16, 0.56**
Middle	64	-410, 538	-14	-235, 208	0.13	-0.10, 0.36	-61	-318, 195	**-425****	**-604, -245**	0.27	0.05, 0.49
High	Ref		Ref		Ref		Ref		Ref		Ref	
Model 2 [b]												
Neighborhood SES												
Low	-2	-512, 508	-101	-236, 123	0.11	-0.13, 0.34	-116	-362, 129	**-266****	**-446, -86**	0.09	-0.08, 0.27
Middle	77	-335, 489	231	-105, 513	-0.08	-0.33, 0.17	-156	-416, 103	**-331****	**-509, -152**	0.13	-0.04, 0.30
High	Ref		Ref		Ref		Ref		Ref		Ref	
Model 3 [b]												
Neighborhood SES												
Low	-21	-591, 550	31	-195, 257	0.05	-0.19, 0.29	-130	-404, 144	**-244****	**-415, -73**	0.04	-0.13, 0.21
Middle	80	-325, 486	319	-13, 651	-0.11	-0.34, 0.12	-183	-452, 87	**-328****	**-507, -148**	0.10	-0.07, 0.26
High	Ref		Ref		Ref		Ref		Ref		Ref	
Model 4 [b]												
Neighborhood SES												
Low	78	-478, 545	47	-180, 274	0.04	-0.19, 0.28	-205	-475, 64	**-256****	**-409, -93**	-0.01	-0.19, 0.16
Middle	168	-347, 1775	**313***	**9, 618**	-0.12	-0.35, 0.11	-227	-478, 24	**-330****	**-501, -159**	0.06	-0.11, 0.24
High	Ref		Ref		Ref		Ref		Ref		Ref	

[a] Indicates a significant trend for potassium among men, $P<0.05$; [b] Indicates a significant trend for potassium among women, $P<0.05$

[c] Indicates a significant trend for Na-K among men, $P<0.05$; [d] Indicates a significant trend for Na-K among women, $P<0.05$

Model 1 is unadjusted; model 2 is adjusted for individual-level age, and race/ethnicity; Model 3 is additionally adjusted for individual-level education, poverty, and employment status; model 4 is additionally adjusted for physical activity.

Abbreviations: CI: confidence interval; Na-K: sodium to potassium ratio; SES: socio-economic status.

Boldface indicates statistical significance (** $P<0.01$; * $P<0.05$)

DISCUSSION

Findings from this study suggest strong associations between lower neighborhood SES and higher BMI and WC, and lower urinary potassium excretion among women but not men. Among women, residing in a low vs. high SES neighborhood was associated with a 2.19 kg/m^2 higher BMI and a 251 mg/day lower urinary potassium excretion, above and beyond individual-level characteristics. Our results suggest that women may be particularly vulnerable to obesogenic and other negative effects of a socioeconomically disadvantaged neighborhood.

A number of studies have pointed to an association between neighborhood SES and measures of obesity.[6,7,9,38] For example, findings from the Dallas Heart Study, a multiethnic cohort, showed that moving from a higher to a lower SES neighborhood was associated with weight gain.[7] Likewise, among women of the Black Women's Health Study, lower neighborhood SES was associated with weight gain over 10 years.[39] Though neither of these studies focused on differences by sex. In our multiethnic cohort of NYC adult residents—using a more comprehensive measure of neighborhood SES, we too found that living in a low SES neighborhood was associated with measures of obesity such as higher BMI, and the association was only present in women. Prior work has shown individual-level SES to be more strongly associated with obesity in women than in men.[1] However, neighborhood effects on measures of obesity by sex yielded mixed findings.[24-27] For example, among participants of the 1986 American's Changing Lives Study, neighborhood poverty was associated with higher BMI among women but not men.[26] Results from the Multi-Ethnic Study of Atherosclerosis found no association between the social environment and BMI among women.[27] Further studies exploring associations between the neighborhood environment and obesity, and whether or not these associations vary across different groups, are warranted to better understand the impacts of residing in low SES neighborhoods and to guide the design of more tailored and comprehensive interventions.

Low neighborhood SES was not associated with urinary sodium excretion in men or women. Given the low intraclass correlation coefficient for sodium, indicative of no neighborhood level sodium clustering, our null findings were expected. Our results are in accordance with previous findings from the HFUS cohort showing no association between neighborhood-level poverty and individual-level sodium intake.[19] Similarly, results from the Japan Dietetic Students' Study for Nutrition and Biomarkers Study Group, a Japanese cohort of young women showed no association between neighborhood SES and 24-hour urinary sodium excretion.[40] These results may point to the ubiquity of sodium in the US food supply,[41] such that everyone is exposed regardless of the SES of the neighborhood they live in. In fact, it is estimated that approximately 80% of sodium consumed is derived from prepackaged, and restaurant foods;[41,42] therefore limiting individual ability to control sodium intake. In the current study, daily sodium intake overall was 3,240 mg/day, well exceeding 2015 US Department of Agriculture recommendations of no more than 2,300 mg per day;[43] this was true among all tertiles of neighborhood SES.

Unlike with sodium, our findings showed significant associations between neighborhood SES and 24-hour urinary potassium excretion, an objective indicator of fruit and vegetable consumption[44] and healthy diet.[21] As potassium is an important nutrient that helps lower blood pressure,[45] the strength of these results cannot be underscored; a 251 mg/day difference is substantial—especially on a population wide basis—considering recommended intake should be 4700 mg/day,[43] and that mean potassium intake overall was only 2,182 mg/day. Though we did directly not assess reasons for neighborhood differences in potassium intake, these findings have important public health implications and highlight that certain neighborhoods may require additional intervention (i.e. access or affordability of fruits and vegetables). Importantly, our findings are consistent with other studies,[11,12,40,46,47] yet mostly using self-reported fruit and vegetable consumption. For example, findings from the National Health Nutrition and Examination survey showed that higher neighborhood SES was associated with increased fruit and vegetable intake.[11] Likewise, findings from the New York City Community Health Survey have shown that residing in a neighborhood of low vs. high SES was associated with reporting lower fruit and vegetable intake.[12] Prior studies have also linked other neighborhood characteristics, such as neighborhood retail environment, to individual diet quality, including potassium.[46] For example, among participants of the Japan Dietetic Students' Study for Nutrition and Biomarkers Study Group, neighborhood availability of supermarkets was associated with higher urinary potassium excretion.[13] Finally, previous HFUS findings showed that neighborhood poverty was not associated with 24 hour urinary excretion of potassium.[19] However, this study used different methods which likely accounted for the discrepant findings. For example, the current analysis includes more neighborhood level units (i.e. 128 vs. 42 neighborhoods), a different neighborhood SES construct comprised of multiple dimensions of SES rather than just poverty, and sex stratified models. Had we used overall rather than sex-stratified models, associations for potassium would have been null.

Previous studies have signaled that the associations between individual-level SES and fruit and vegetable consumption may vary by sex.[44] However, to our knowledge, no prior studies in the US have formally assessed whether the relationship of neighborhood-level SES and diet quality, measured objectively—such as 24-hour urinary potassium excretion, varies by sex. In our study, we found neighborhood SES to be associated with potassium excretion among women but not men. It has been hypothesized that in general, neighborhood level effects might be stronger for women than men considering women may spend more time in the home and within their neighborhoods.[48] Further, it has been proposed that the neighborhood food environment (often correlated with neighborhood SES)[49] may drive differences in diet quality.[50] With women more likely to be primary grocery shoppers, it is perhaps not surprising that associations between the neighborhood environment and diet quality are more pronounced among women.

Finally, our study found that residing in a neighborhood of low vs. high SES was associated with a 0.40 and 0.36 unit higher Na-K ratio in men and women respectively, in unadjusted models. Individuals consuming USDA recommendations[43] for sodium (< 2300 mg/day) and potassium (≥4700 mg/day) would have an Na-K ratio of 0.49. Thus differences in the order of 0.4 in magnitude are substantial; though these findings were not significant in adjusted models. Though limited studies exist, our findings are somewhat consistent with a study of Japanese women showing that low vs. high neighborhood SES was associated with higher Na-K ratio, adjusting for only survey year, living status, and region of residence.[40]

The current research has a few limitations that are worth noting. First, while our study was population based and representative of non-institutionalized NYC adults, our results may not necessarily be extrapolated to other geographical locations given the uniqueness of NYC neighborhoods. Further, we relied on zip codes to define neighborhoods; zip codes may encompass a more diverse SES composition and therefore introduce heterogeneity into the measure. Despite this, we believe the use of zip code is appropriate for the following reasons: 1) NYC is a densely populated area and so zip codes encompass much smaller geographical bounds than in other locations, and 2) any heterogeneity introduced in our measure would likely bias results towards the null. Yet, we still found substantial and strong neighborhood level effects. Additionally, 24-hour urine measures reflect sodium and potassium intake during the previous day and may not necessarily be indicative of habitual sodium and potassium consumption. Further though we were adequately powered to test for interaction by sex, stratification by sex resulted in smaller sample sizes and notably limited the precision our estimates—particularly for our dietary factors of sodium and potassium which are highly variable. Finally, the HFUS was cross-sectional, thus any observed associations may reflect self-selection of certain individuals into certain neighborhoods rather than the effect of a neighborhood on an individual's health.

Despite such limitations, the study possesses noteworthy strengths. Our measure of neighborhood SES was rich as it utilized several SES domains. Additionally, we utilized two measures of obesity: BMI, as a measure of total fat, and WC as a measure of central adiposity.[34] Both BMI and WC have respective limitations: with BMI unable to account for body fat distribution or muscle mass, and WC unable to account for height.[34] Given the limitations of each measure on its own, the consistency of our results across both measures added strength to the findings. Also notable, our outcomes were objectively measured and therefore subject to less measurement error. This is particularly true of our dietary measures, the HFUS study is the first population-based representative study in the US to use the gold-standard of 24-hour urine to measure sodium and potassium intake.

CONCLUSIONS:

In our study, representative of NYC adults, residing in a low vs. high SES neighborhood was associated with measures of obesity and lower urinary potassium excretion among women but not men. This research contributes to the growing body of evidence showing that the neighborhood environment is associated with health. We highlight that the association of SES with obesity and potassium—an objective dietary biomarker—is moderated by sex. Future research related to neighborhood level effects should focus on exploring such sex differences.

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Contributor Statement

Dr. Elfassy conducted the statistical analyses for this study. Drs. Elfassy and Zeki Al Hazzouri interpreted the data and drafted the manuscript. Drs. Elfassy, Yi, Llabre, Schneiderman, Gellman, Florez, Prado, and Zeki Al Hazzouri contributed to the methodological aspects of this study and were all involved with critical review of the manuscript. The authors have no relevant financial disclosures to report.

Data Sharing Statement:

No additional data available

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STROBE Statement—checklist of items that should be included in reports of observational studies

	Item No	Recommendation
Line Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract: see title and line 10 of page 5
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found: see abstract on page 5
Introduction		
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported: see introduction on page 7
Objectives	3	State specific objectives, including any prespecified hypotheses: see page 8 line 8
Methods		
Study design	4	Present key elements of study design early in the paper: see page 8 lines 25-50
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection: see page 8 lines 25-50
Participants	6	(*a*) *Cohort study*—Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up: *Case-control study*—Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls NA *Cross-sectional study*—page 10 lines 54-page 11 line 8
		(*b*) *Cohort study*—For matched studies, give matching criteria and number of exposed and unexposed NA *Case-control study*—For matched studies, give matching criteria and the number of controls per case NA
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable: see page 8 line 55 – page 10 line 47
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group: see page 8 line 55 – page 10 line 47
Bias	9	Describe any efforts to address potential sources of bias: page 23 lines 6-11
Study size	10	Explain how the study size was arrived at: page 10 line 54 – page 11 line 8
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why: page 10 lines 17-47
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding: page 11
		(*b*) Describe any methods used to examine subgroups and interactions: page 11 lines 45-50
		(*c*) Explain how missing data were addressed: page 10 lines 54-page 11 line 8
		(*d*) *Cohort study*—If applicable, explain how loss to follow-up was addressed NA *Case-control study*—If applicable, explain how matching of cases and controls was addressed NA *Cross-sectional study*—If applicable, describe analytical methods taking account of sampling strategy: complex survey design-page 11 line 54 – page 12 line 6
		(*e*) Describe any sensitivity analyses : n/a

Results		
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed: page 10 lines 54-page 11 line 8
		(b) Give reasons for non-participation at each stage- page 10 lines 54-page 11 line 8
		(c) Consider use of a flow diagram:
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders: table 1 (page 13) and page 12 and page 13
		(b) Indicate number of participants with missing data for each variable of interest: page 10 lines 54-page 11 line 8
		(c) *Cohort study*—Summarise follow-up time (eg, average and total amount) NA
Outcome data	15*	*Cohort study*—Report numbers of outcome events or summary measures over time NA
		Case-control study—Report numbers in each exposure category, or summary measures of exposure NA
		Cross-sectional study—Report numbers of outcome events or summary measures: NA-outcome is continuous. Beta estimates are reported in the tables (pages 17 and 19)
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included: see tables 3 (page 17) and table 4 (page 19), adjustments are clear
		(*b*) Report category boundaries when continuous variables were categorized-we used tertiles of a factor score, page 10, lines 17-47
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period-NA
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses
Discussion		
Key results	18	Summarise key results with reference to study objectives: Page 20 lines 6-17
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias: page 22, lines 31-49
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence: page 23, lines 17-29
Generalisability	21	Discuss the generalisability (external validity) of the study results: page 23 lines 6-8
Other information		
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based: provided at the end of the manuscript: page 23 line 36-page 24 line 10