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Neighbourhood socioeconomic status and cross-sectional associations with obesity and urinary biomarkers of diet among New York City adults: the heart follow-up study

Tali Elfassy,[1] Stella S Yi,[2] Maria M Llabre,[3] Neil Schneiderman,[3] Marc Gellman,[3] Hermes Florez,[1] Guillermo Prado,[1] Adina Zeki Al Hazzouri[1]

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[1]Department of Public Health Sciences, University of Miami, Miami, Florida, USA
[2]Department of Population Health, New York University School of Medicine, New York, USA
[3]Department of Psychology, University of Miami, Coral Gables, Florida, USA

Correspondence to
Dr Tali Elfassy;
t.elfassy@med.miami.edu

ABSTRACT

Objective To determine whether neighbourhood socioeconomic status (SES) is associated with body mass index (BMI), waist circumference (WC) 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 1645 adults.

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

Primary and secondary outcome measures BMI (kg/m^2) and WC (inches) were measured during in-home visits, and 24-hour urine sample 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 versus high neighbourhood SES tertile was associated with 1.83 kg/m^2 higher BMI (95% CI 0.41 to 3.98) and 251 mg/day lower potassium excretion (95% CI −409 to 93) among women only, with no associations among men (P values for neighbourhood SES by sex interactions <0.05).

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

Trial registration number NCT01889589; Results.

Strengths and limitations of this study

- These data come from the New York City (NYC) Heart Follow-up Study and are population-based and representative of the NYC adult population.
- Modelled as tertiles of a factor score, the main exposure of interest, neighbourhood socioeconomic status, was constructed based on neighbourhood 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 neighbourhoods.

INTRODUCTION

Poor socioeconomic 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 behaviours[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 behaviours 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 neighbourhood characteristics, such as neighbourhood safety and neighbourhood 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 neighbourhood 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 neighbourhood 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 neighbourhood 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 neighbourhood 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 neighbourhood SES, obesity and diet quality using data from the Heart Follow-up Study (HFUS), a population-based[30] 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 NYC Community Health Survey (CHS) HFUS is a cross-sectional study conducted in 2010 to assess population-based sodium intake from a representative sample of 1775 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 6342 participants were screened for HFUS eligibility with 5830 deemed eligible (not pregnant, lactating or undergoing kidney dialysis). Of eligible participants, a total of 1775 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, aliquoted the urine and sent it directly to the research laboratory. All study participants provided informed consent.

Measures of obesity

For obesity, we considered two outcome measures: BMI as a measure of total fat and 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 metre 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 analysed for sodium, potassium and creatinine. Sodium and potassium were measured using the ion-selective electrode potentiometric method on the Roche DPP Modular analyser. Creatinine, used to assess urine completeness,[20] was measured using the Jaffe kinetic colorimetric method on the same analyser. All laboratory values were normalised 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 labour 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 neighbourhoods. Neighbourhood safety was reported in response to the question of 'How safe from crime do you consider your neighbourhood to be' with responses including 'extremely safe,' 'quite safe,' 'slightly safe' or 'not safe at all'; answers were then dichotomised into two categories: an unsafe neighbourhood ('slightly safe' or 'not safe at all' responses) versus a safe neighbourhood ('extremely safe' or 'quite safe' responses).

Neighbourhood SES

Neighbourhoods were defined according to zip codes which were retrieved from participants' addresses. Individual-level responses for household poverty level, educational attainment, employment and perceived neighbourhood safety (all defined above) were aggregated by neighbourhood to create neighbourhood-level variables for: proportion of households in the neighbourhood with income 100% below the FPL, proportion of individuals in the neighbourhood who are unemployed, proportion of individuals in the neighbourhood with less than a HS education and proportion of individuals in the neighbourhood who report living in an unsafe neighbourhood. All neighbourhood-level variables were expressed as a proportion with a potential range of 0%–100%. Then, using the principle factor method, we created a neighbourhood SES factor score using these neighbourhood-level variables; all neighbourhood-level variables met a loading threshold criteria of 0.3. Finally, we created tertiles from the neighbourhood SES score to further characterise neighbourhoods 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 geographical residence (zip code) information, resulting in a final analytic sample of 1645 individuals.

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

To determine whether a multilevel model and analyses were appropriate, we calculated intraclass correlation coefficients (ICCs) which calculate for each outcome of interest the per cent of total variance that is between neighbourhoods. 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 ICCs are of relatively small magnitude, we were uniquely interested in the associations of neighbourhood-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 neighbourhood 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 analysed in 2016 with survey weights and design variables using SUDAAN (V.10.0; Research Triangle Institute, Research Triangle Park, North Carolina, USA) and MPLUS (V/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.

The proportion of households with income <100% of the FPL and the proportion of individuals reporting living in an unsafe neighbourhood was highest (38% and 56%, respectively) in the lowest neighbourhood SES score tertile and lowest in the highest neighbourhood SES tertile (6% and 10%, respectively), data are 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 neighbourhood SES tertile and lowest in the highest neighbourhood SES tertile (6% and 7%, respectively).

Mean 24-hour urinary sodium excretion was 3240 mg/day and did not differ significantly by neighbourhood tertile in men or women (table 2). Among men, those living in a low versus high SES neighbourhoods 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 versus high SES neighbourhood 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 versus high SES neighbourhoods 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).

In unadjusted and fully adjusted models, neighbourhood 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 neighbourhood SES was not associated with individual-level BMI or WC (table 3). Among women, in unadjusted models, living in a low versus high and middle versus high neighbourhood SES was significantly associated with 3.60 kg/m^2 (95% CI 2.00 to 5.19) and 2.21 kg/m^2 (95% CI 1.00 to 3.43) higher BMI; P for trend <0.05. Likewise, living in a low versus high and middle versus high neighbourhood SES was significantly associated with 2.94 inches (95% CI 0.80 to 5.09) and 2.00 inches (95% CI 0.46 to 3.58) larger WC; P for trend <0.05. In fully adjusted models, living in a low versus high or middle versus high SES neighbourhood remained associated with 2.19 kg/m^2 (95% CI 0.41 to 3.98) and 1.83 kg/m^2 (95% CI 0.34 to 3.31) higher BMI; P for trend <0.05. Living in a middle

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

Characteristic	Overall (N=1645) %	Overall SE	Men (n=689) %	Men SE	Women (n=956) %	Women SE
Age group (years)						
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 graduate	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**
Do not 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 labour 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

Boldface indicates statistical significant differences comparing men with women. *P<0.05, **P<0.01.
†Estimates are age standardised to the US 2000 population.
FPL, federal poverty level; HS, high school.

versus high neighbourhood SES remained significantly associated with 1.86 inches (95% CI 0.22 to 3.50) larger WC.

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

DISCUSSION

Findings from this study suggest strong associations between lower neighbourhood SES and higher BMI and WC, and lower urinary potassium excretion among women but not men. Among women, residing in a low versus high SES neighbourhood 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

Table 2 Mean obesity and dietary characteristics overall and across tertiles of neighbourhood SES score, by sex†

	Overall		Men						Women					
			Tertile of n eighbourhood SES s core						Tertile of n eighbourhood SES s core					
			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/m^2)	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)	3240	58	2699	159	3734	134	3377	159	2961	106	2865	108	3013	150
Potassium (mg/day)	2182	38	**2131***	**87**	2667	135	2404	92	**1911****	**63**	**1890****	61	2238	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

Boldface indicates statistical significant differences when compared with high neighbourhood SES using t-tests.*P<0.05, **P<0.01.
†Estimates are age standardised to the US 2000 population.
BMI, body mass index; Na:K, sodium to potassium ratio; SES, socioeconomic status.

negative effects of a socioeconomically disadvantaged neighbourhood.

A number of studies have pointed to an association between neighbourhood 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 neighbourhood was associated with weight gain.[7] Likewise, among women of the Black Women's Health Study, lower neighbourhood 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 neighbourhood SES, we too found that living in a low SES neighbourhood 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, neighbourhood effects on measures of obesity by sex yielded mixed findings.[24–27] For example, among participants of the 1986 American's Changing Lives Study, neighbourhood poverty was associated with higher BMI among women but not men.[26] Results from the MultiEthnic Study of Atherosclerosis found no association between the social environment and BMI among women.[27] Further studies exploring associations between the neighbourhood 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 neighbourhoods and to guide the design of more tailored and comprehensive interventions.

Low neighbourhood SES was not associated with urinary sodium excretion in men or women. Given the low ICC for sodium, indicative of no neighbourhood-level sodium clustering, our null findings were expected. Our results are in accordance with previous findings from the HFUS cohort showing no association between neighbourhood-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 neighbourhood 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 neighbourhood 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 3240 mg/day, well exceeding 2015 US Department of Agriculture recommendations of no more than 2300 mg per day[43]; this was true among all tertiles of neighbourhood SES.

Unlike with sodium, our findings showed significant associations between neighbourhood 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

Table 3 Associations of tertiles of neighbourhood SES score with BMI and WC by sex

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

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.
Boldface indicates statistical significance. *P<0.05, **P<0.01.
†Indicates a significant trend for BMI among women, P<0.05.
‡Indicates a significant trend for waist circumference among women, P<0.05.
BMI, body mass index; SES, socioeconomic status; WC, waist circumference.

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 2182 mg/day. Though we did directly not assess reasons for neighbourhood differences in potassium intake, these findings have important public health implications and highlight that certain neighbourhoods may require additional intervention (ie, 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 neighbourhood SES was associated with increased fruit and vegetable intake.[11] Likewise, findings from the NYC CHS have shown that residing in a neighbourhood of low versus high SES was associated with reporting lower fruit and vegetable intake.[12] Prior studies have also linked other neighbourhood characteristics, such as neighbourhood 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, neighbourhood availability of supermarkets was associated with higher urinary potassium excretion.[13] Finally, previous HFUS findings showed that neighbourhood 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 neighbourhood-level units (ie, 128 vs 42 neighbourhoods), a different neighbourhood SES construct comprised 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 signalled 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 USA have formally assessed whether the relationship of neighbourhood-level SES and diet quality, measured objectively—such as 24-hour urinary potassium excretion, varies by sex. In our study, we found neighbourhood SES to be associated with

Table 4 Associations of tertiles of neighbourhood 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†‡§¶												
Neighbourhood SES												
Low	12	−426 to 451	**−403****	**−628** to **178**	**0.40****	**0.13** to **0.66**	42	−217 to 301	**−426****	**−614** to **238**	**0.36****	**0.16** to **0.56**
Middle	64	−410 to 538	−14	−235 to 208	0.13	−0.10 to 0.36	−61	−318 to 195	**−425****	**−604** to **245**	0.27	0.05 to 0.49
High	Reference		Reference		Reference		Reference		Reference		Reference	
Model 2‡												
Neighbourhood SES												
Low	−2	−512 to 508	−101	−236 to 123	0.11	−0.13 to 0.34	−116	−362 to 129	**−266****	**−446** to **86**	0.09	−0.08 to 0.27
Middle	77	−335 to 489	231	−105 to 513	−0.08	−0.33 to 0.17	−156	−416 to 103	**−331****	**−509** to **152**	0.13	−0.04 to 0.30
High	Reference		Reference		Reference		Reference		Reference		Reference	
Model 3‡												
Neighbourhood SES												
Low	−21	−591 to 550	31	−195 to 257	0.05	−0.19 to 0.29	−130	−404 to 144	**−244****	**−415** to **73**	0.04	−0.13 to 0.21
Middle	80	−325 to 486	319	−13 to 651	−0.11	−0.34 to 0.12	−183	−452 to 87	**−328****	**−507** to **148**	0.10	−0.07 to 0.26
High	Reference		Reference		Reference		Reference		Reference		Reference	
Model 4‡												
Neighbourhood SES												
Low	78	−478 to 545	47	−180 to 274	0.04	−0.19 to 0.28	−205	−475 to 64	**−251****	**−409** to **93**	−0.01	−0.19 to 0.16
Middle	168	−347 to 1775	**313***	**9** to **618**	−0.12	−0.35 to 0.11	−227	−478 to 24	**−330****	**−501** to **19**	0.06	−0.11 to 0.24
High	Reference		Reference		Reference		Reference		Reference		Reference	

Model 1 is unadjusted; Model two 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.
Boldface indicates statistical significance *P<0.05, **P<0.01.
†Indicates a significant trend for potassium among men, P<0.05.
‡Indicates a significant trend for potassium among women, P<0.05.
§Indicates a significant trend for Na–K among men, P<0.05.
¶Indicates a significant trend for Na–K among women, P<0.05.
Na:K, sodium to potassium ratio; SES, socioeconomic status.

potassium excretion among women but not men. It has been hypothesised that in general, neighbourhood-level effects might be stronger for women than men considering women may spend more time in the home and within their neighbourhoods.[48] Further, it has been proposed that the neighbourhood food environment (often correlated with neighbourhood 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 neighbourhood environment and diet quality are more pronounced among women.

Finally, our study found that residing in a neighbourhood of low versus 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 versus high neighbourhood 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-institutionalised NYC adults, our results may not necessarily be extrapolated to other geographical locations given the uniqueness of NYC neighbourhoods. Further, we relied on zip codes to define neighbourhoods; 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 neighbourhood-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 neighbourhoods rather than the effect of a neighbourhood on an individual's health.

Despite such limitations, the study possesses noteworthy strengths. Our measure of neighbourhood SES was rich as it used several SES domains. Additionally, we used 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 USA to use the gold standard of 24-hour urine sample to measure sodium and potassium intake.

CONCLUSIONS

In our study, representative of NYC adults, residing in a low versus high SES neighbourhood 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 neighbourhood 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 neighbourhood-level effects should focus on exploring such sex differences.

Contributors TE conducted the statistical analyses for this study. TE and AZAH interpreted the data and drafted the manuscript. TE, SY, MML, NS, MG, HF, GP and AZAH contributed to the methodological aspects of this study and were all involved with critical review of the manuscript.

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