American Journal of
Preventive Medicine

RESEARCH ARTICLE

Associations of Obesity and Neighborhood Factors With Urinary Stone Parameters

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Introduction: Obesity is associated with kidney stone disease, but it is unknown whether this association differs by SES. This study assessed the extent to which obesity and neighborhood characteristics jointly contribute to urinary risk factors for kidney stone disease.

Methods: This was a retrospective analysis of adult patients with kidney stone disease evaluated with 24-hour urine collection (2001−2020). Neighborhood-level socioeconomic data were obtained for a principal component analysis, which identified 3 linearly independent factors. Associations between these factors and 24-hour urine measurements were assessed using linear regression as well as groupings of 24-hour urine results using multivariable logistic regression. Finally, multiplicative interactions were assessed testing effect modification by obesity, and analyses stratified by obesity were performed. Analyses were performed in 2021.

Results: In total, 1,264 patients met the study criteria. Factors retained on principal component analysis represented SES, family structure, and housing characteristics. On linear regression, there was a significant inverse correlation between SES and 24-hour urine sodium (p=0.0002). On multivariable logistic regression, obesity was associated with increased odds of multiple stone risk factors (OR=1.61; 95% CI=1.15, 2.26) and multiple dietary factors (OR=1.33; 95% CI=1.06, 1.67). No significant and consistent multiplicative interactions were observed between obesity and quartiles of neighborhood SES, family structure, or housing characteristics.

Conclusions: Obesity was associated with the presence of multiple stone risk factors and multiple dietary factors; however, the strength and magnitude of these associations did not vary significantly by neighborhood SES, family structure, and housing characteristics.

Am J Prev Med 2022;63(1S1):S93−S102.

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This article is part of a supplement entitled Obesity-Related Health Disparities: Addressing the Complex Contributors, sponsored by the National Institute on Minority Health and Health Disparities (NIMHD), part of the National Institutes of Health (NIH), an agency of the U.S. Department of Health and Human Services (HHS).

0749-3797/$36.00

https://doi.org/10.1016/j.amepre.2022.01.033

INTRODUCTION

Kidney stone disease (KSD) affects nearly 1 in 11 adults.[1] At least 50% of adults with a stone-related event will experience another one within 10 years.[2] Thus, KSD is best viewed as a chronic disease. Clinical guidelines recommend metabolic testing consisting of 24-hour urine collections for recurrent stone formers and high-risk or interested first-time stone formers.[3] Differences in contributors to stone formation, including 24-hour urine findings, can be due to nutrition, lifestyle, or physiologic responses; many of which can be modified through secondary prevention.

To date, there is limited research evaluating the influence of SES on urinary risk factors for KSD. A recent scoping review evaluating disparities in KSD in the U.S.[4] identified only 3 studies focused on the associations between socioeconomic factors and urine chemistry.[5−7] The relationship between SES and urine chemistry among stone formers is further complicated by the risk factors that may vary by sociodemographic group. Obesity is one such risk factor for KSD.[8] The relationship between obesity and SES is complex,[9] and it is unclear whether an interaction between obesity and SES influences urinary risk factors for KSD.

To better understand the joint influence of obesity and SES on urinary risk factors for KSD, an analysis of 24-hour urine data from adult kidney stone formers with available BMI and neighborhood-level socioeconomic data was performed. Owing to the multidimensional nature of neighborhood SES, a principal component analysis (PCA) was performed. Associations with individual 24-hour urine testing results as well as 2 groupings of these results were evaluated. Finally, interactions between neighborhood characteristics and obesity were tested to determine whether they influenced the outcomes mentioned earlier.

METHODS

Study Sample

This was a retrospective evaluation of prospectively collected data among patients with KSD evaluated with 24-hour urine collection at an academic medical center. Patients aged ≥18 years who completed at least 1 collection between 2001 and 2020 met inclusion criteria. The steps in study sample development are shown in Appendix Figure 1 (available online). Patients without at least 1 BMI measurement, patients with diagnoses or procedures associated with gastrointestinal malabsorption (codes listed in Appendix Table 1, available online), patients with missing Census tract information, patients not residing in Alabama or a neighboring state, and patients without at least 1 adequate 24-hour urine creatinine (Cr) as defined by Taylor and Curhan (>600 mg for a female patient and >800 mg for a male patient)[10] were excluded. The IRB at the University of Alabama at Birmingham approved this study.

Measures

Patient age at the time of the first 24-hour urine collection, sex, marital status, race, and ethnicity were reported. The BMI reported with the patient's 24-hour urine result was used. If one was not reported, the most recent BMI in the electronic medical record on or before the collection date was used. The diagnosis codes used to define chronic kidney disease, diabetes, and hypertension are available through the Chronic Conditions Data Warehouse.[11] For patients who underwent a stone removal procedure (ureteroscopic stone removal or percutaneous nephrolithotomy) with an available stone analysis, a cutoff >50% to define predominant stone composition was applied.

To obtain neighborhood data, each patient's charted residential address at the time of the analysis was geocoded and linked to the 2017 American Community Survey 5-year estimates aggregated to Census tracts.[12] A total of 15 variables in the domains of education, income, disability, healthcare access, family structure, and housing and living conditions were obtained to examine the relationship between neighborhood disadvantage and KSD. Variables are listed in Appendix Table 2 (available online); all measures were expressed as percentages.

Litholink (Laboratory Corporation of America, Burlington, NC) chemically analyzed all 24-hour urine collections.[13] The measurements on which stone risk factors were defined included urine volume, calcium, oxalate, citrate, pH, and uric acid. Relative supersaturation indices were not included. The measurements on which dietary factors were defined included urine sodium, potassium, magnesium, phosphorus, ammonium, sulfate, and urea nitrogen. Appendix Table 3 (available online) defines how measurements were classified as abnormal. The 2 outcomes of interest in this study were the presence of (1) multiple (>1) stone risk factors and (2) multiple (>1) dietary factors, as defined in Litholink reports. These outcomes were determined using each patient's first adequate 24-hour urine collection on the basis of urine Cr.

Statistical Analysis

A PCA identified neighborhood characteristics explaining the variance in the study sample. This allowed a multidimensional evaluation of neighborhood characteristics, which was preferred over a single index of neighborhood disadvantage. The PCA resulted in 3 factors on the basis of eigenvalues >1, accounting for 72% of the variance. Factor eigenvalues and loadings are listed in Table 1. For all subsequent analyses, neighborhood factors were assessed as standardized scores (mean=0, SD=1), with higher scores representing higher disadvantage.

Differences in patient and neighborhood characteristics stratified by the 2 outcomes of interest (multiple stone risk factors and multiple dietary factors) were evaluated using chi-square tests to assess differences in categorical variables, 2-sample *t*-tests to assess differences in continuous variables, and appropriate nonparametric tests when assumptions of parametric tests were not met. An exploratory analysis assessed individual 24-hour urine measurements and the 3 neighborhood factors as continuous variables using linear regression. Multivariable logistic regression models evaluated the associations between the 3 neighborhood factors and the 2 outcomes of interest. Effect modification by obesity (BMI ≥30 kg/m^2) was assessed by testing the statistical significance of multiplicative interaction terms and building models stratified by obesity. Finally, a secondary analysis was performed

Table 1. Factor Eigenvalues and Loadings of Neighborhood Variables Derived Through a Principal Component Analysis

Variables	Factor 1: SES, eigenvalue=7.89	Factor 2: family structure, eigenvalue=1.49	Factor 3: housing characteristics, eigenvalue=1.38
Adults aged ≥25 years without a high-school diploma	**0.83**	−0.19	−0.18
Adults aged ≥25 years with bachelor's degree	−**0.82**	0.22	0.21
Households in poverty	**0.83**	0.38	0.06
Households with SNAP/food stamp benefits	**0.90**	0.25	0.00
Civilian unemployment rate	**0.73**	0.19	−0.02
Disabled population	**0.76**	−0.38	−0.10
Civilians without health insurance	**0.78**	0.14	−0.02
Civilians with private health insurance	−**0.95**	−0.11	0.03
Households with computer access	−**0.87**	0.30	0.02
Households with broadband access	−**0.90**	0.24	0.08
Households without vehicles	**0.65**	0.16	0.30
Single-parent households with children	0.51	**0.69**	0.05
Households with seniors (aged ≥65 years) living alone	0.38	−**0.56**	0.21
Households lacking complete kitchen facilities	0.10	−0.03	**0.81**
Households lacking complete plumbing facilities	0.16	−0.15	**0.70**

Note: Boldface indicates the loading with the greatest absolute value corresponding to each variable.
SNAP, Supplemental Nutrition Assistance Program.

by excluding patients without at least 1 appropriate 24-hour urine Cr as defined by the stricter Litholink cutoffs (18–24 mg/kg for a male patient and 15–20 mg/kg for a female patient).[13]

Statistical analyses and plot generation were performed in 2021 using SAS, version 9.4 (SAS Institute, Inc., Cary, NC); MATLAB, version R2021a (Math Works, Inc., Natick, MA); and PRISM, version 9.2.0 (GraphPad Software, LLC, San Diego, CA). All statistical tests were 2 sided, and $p<0.05$ were considered statistically significant, except for the linear regressions in which a Bonferroni correction was applied to correct for multiple testing (statistical significance was $p\leq0.001$ for these 39 analyses).

RESULTS

The analytic sample included 1,264 adult patients: mean age 51.1 years (SD 15.1), 649 (51.3%) male, 482 (38.1%) obese (Appendix Figure 1, available online). The median time between the recorded BMI and 24-hour urine result was 25 days (IQR=12–82 days); this difference exceeded 1 year for 205 of 1,264 (16.2%) patients. As detailed in Table 1, the PCA generated 3 neighborhood-level factors, representing SES (Factor 1), family structure (Factor 2), and housing characteristics (Factor 3).

Individual- and neighborhood-level characteristics of the analytic sample are listed in Table 2. Patients with multiple stone risk factors resided in neighborhoods with higher rates of poverty and single-parent households with children and lower rates of private health insurance coverage than those without multiple stone risk factors. Patients with multiple dietary factors resided in neighborhoods with higher rates of adults aged ≥25 years without a high-school diploma and disability and lower rates of adults aged ≥25 years with a bachelor's degree than those without multiple dietary factors. There were also statistically significant differences in marital status and BMI (Table 2).

Results of an exploratory analysis correlating 24-hour urine measurements with neighborhood SES, family structure, and housing characteristics through linear regression are shown in Appendix Figure 2 (available online) for stone risk factors and Appendix Figure 3 (available online) for dietary factors. Of the 39 regressions performed, only 1 showed a statistically significant correlation after correction for multiple testing: 24-hour urine sodium was positively correlated with neighborhood SES (Factor 1) (p=0.0002).

Table 2. Individual and Neighborhood Characteristics of the Study Sample

Characteristic	Overall (N=1,264)	One or fewer stone risk factors (*n*=195)	Multiple stone risk factors (*n*=1,069)	*p*-value	One or fewer dietary factors (*n*=648)	Multiple dietary factors (*n*=616)	*p*-value
Individual-level							
Age, years, mean (SD)	51.1 (15.1)	52.3 (13.5)	50.9 (15.3)	0.2	51.6 (15.3)	50.6 (14.8)	0.3
Sex, *n* (%)				0.3			0.3
Female	615 (48.7)	88 (45.1)	527 (49.3)		325 (50.2)	290 (47.1)	
Male	649 (51.3)	107 (54.9)	542 (50.7)		323 (49.9)	326 (52.9)	
Married, *n* (%)	840 (66.5)	141 (72.3)	699 (65.4)	0.15	462 (71.3)	378 (61.4)	**<0.001**
Race, *n* (%)				0.5			0.7
White	985 (77.9)	154 (79.0)	831 (77.7)		508 (78.4)	477 (77.4)	
Black	116 (9.2)	23 (11.8)	93 (8.7)		64 (9.9)	52 (8.4)	
Asian	18 (1.4)	1 (0.5)	17 (1.6)		11 (1.7)	7 (1.1)	
American Indian/Alaska Native	4 (0.3)	0 (0.0)	4 (0.4)		2 (0.3)	2 (0.3)	
Other	111 (8.8)	14 (7.2)	97 (9.1)		49 (7.6)	62 (10.1)	
Multiple	5 (0.4)	0 (0.0)	5 (0.5)		2 (0.3)	3 (0.5)	
Unknown	25 (2.0)	3 (1.5)	22 (2.1)		12 (1.9)	13 (2.1)	
Ethnicity, *n* (%)				0.6			0.09
Non-Hispanic	1,033 (81.7)	162 (83.1)	871 (81.5)		544 (84.0)	489 (79.4)	
Hispanic	13 (1.0)	3 (1.5)	10 (0.9)		7 (1.1)	6 (1.0)	
Unknown	218 (17.2)	30 (15.4)	188 (17.6)		97 (15.0)	121 (19.6)	
BMI, kg/m^2 mean (SD)	29.5 (7.4)	28.0 (6.3)	29.8 (7.5)	**<0.001**	28.7 (6.7)	30.4 (8.0)	**<0.001**
Chronic kidney disease, *n* (%)	394 (31.2)	66 (33.9)	328 (30.7)	0.4	213 (32.9)	181 (29.4)	0.2
Diabetes, *n* (%)	165 (13.1)	26 (13.3)	139 (13.0)	0.9	84 (13.0)	81 (13.2)	0.9
Hypertension, *n* (%)	401 (31.7)	59 (30.3)	342 (32.0)	0.6	221 (34.1)	180 (29.2)	0.06
Predominant stone composition, *n* (%)				0.6			0.2
Calcium oxalate	287 (22.7)	51 (26.2)	236 (22.1)		159 (24.5)	128 (20.8)	
Calcium phosphate	58 (4.6)	8 (4.1)	50 (4.7)		31 (4.8)	27 (4.4)	
Uric acid	34 (2.7)	3 (1.5)	31 (2.9)		14 (2.2)	20 (3.3)	
Other	10 (0.8)	1 (0.5)	9 (0.8)		3 (0.5)	7 (1.1)	
Unknown	875 (69.2)	132 (67.7)	743 (69.5)		441 (68.1)	434 (70.5)	
Neighborhood-level							
SES, Factor 1, mean (SD)				0.10			0.08
Adults aged ≥25 years without high-school diploma	8.1 (5.4)	8.0 (5.5)	8.2 (5.3)	0.6	7.8 (5.4)	8.5 (5.3)	**0.02**
Adults aged ≥25 years with bachelor's degree	18.9 (11.8)	19.7 (12.2)	18.7 (11.7)	0.3	19.9 (12.2)	17.8 (11.4)	**0.002**
Households in poverty	10.7 (8.4)	9.4 (7.8)	11.0 (8.5)	**0.007**	10.7 (8.5)	10.8 (8.4)	0.6

(*continued on next page*)

Table 2. Individual and Neighborhood Characteristics of the Study Sample (*continued*)

Characteristic	Overall (N=1,264)	One or fewer stone risk factors (*n*=195)	Multiple stone risk factors (*n*=1,069)	*p*-value	One or fewer dietary factors (*n*=648)	Multiple dietary factors (*n*=616)	*p*-value
Households with SNAP/food stamp benefits	11.2 (8.7)	10.4 (8.8)	11.4 (8.6)	0.06	10.9 (8.8)	11.5 (8.6)	0.11
Civilian unemployment rate	6.3 (4.2)	6.1 (3.9)	6.3 (4.2)	0.6	6.1 (4.0)	6.5 (4.3)	0.2
Disabled population	15.3 (6.1)	15.2 (6.5)	15.3 (6.1)	0.7	14.9 (6.1)	15.7 (6.1)	**0.009**
Civilians without health insurance	9.2 (5.1)	8.7 (5.3)	9.2 (5.1)	0.10	8.9 (5.0)	9.4 (5.2)	0.06
Civilians with private health insurance	72.2 (13.8)	73.7 (14.8)	71.9 (13.6)	**0.04**	72.9 (13.7)	71.4 (13.8)	0.06
Households with computer access	84.9 (9.2)	85.7 (9.2)	84.8 (9.2)	0.2	85.3 (9.0)	84.6 (9.4)	0.3
Households with broadband access	74.6 (12.6)	75.5 (13.3)	74.4 (12.5)	0.2	75.1 (12.5)	74.1 (12.7)	0.2
Households without vehicles	4.9 (4.9)	4.7 (4.4)	5.0 (4.9)	0.2	5.1 (5.2)	4.7 (4.5)	0.4
Family structure, Factor 2, mean (SD)				0.14			0.3
Single-parent households with children	8.1 (5.2)	7.3 (4.7)	8.2 (5.3)	**0.03**	8.1 (5.3)	8.1 (5.0)	0.6
Households with seniors (aged ≥65 years) living alone	10.9 (4.5)	10.7 (4.5)	10.9 (4.4)	0.5	10.9 (4.5)	10.8 (4.4)	0.8
Housing characteristics, Factor 3, mean (SD)				1.0			**0.02**
Households lacking complete kitchen facilities	0.7 (1.1)	0.6 (1.0)	0.7 (1.1)	0.7	0.7 (1.1)	0.6 (1.0)	0.5
Households lacking complete plumbing facilities	0.3 (0.7)	0.3 (0.6)	0.3 (0.7)	0.8	0.3 (0.7)	0.3 (0.7)	0.7

Note: Boldface indicates statistical significance ($p<0.05$).
SNAP, Supplemental Nutrition Assistance Program.

This implies an inverse relation between 24-hour urine sodium and SES because a higher Factor 1 standardized score represents a higher socioeconomic disadvantage.

Results from multivariable logistic regression models of associations of neighborhood SES, family structure, and housing characteristics with the 2 outcomes of interest (multiple stone risk factors and multiple dietary factors) are listed in Table 3. Patients aged 35−49 years had lower odds of multiple stone risk factors than those aged 18−34 years; Black patients had lower odds of multiple stone risk factors than White patients; and patients with obesity had higher odds of multiple stone risk factors than those without obesity. No statistically significant differences in the odds of multiple stone risk factors by neighborhood characteristics (Factors 1−3 quartiles) were detected. For the second outcome, multiple dietary factors, patients who were married had lower odds than those who were not married, and patients with obesity had higher odds than those without obesity. Again, no statistically significant differences in the odds of multiple dietary factors by neighborhood characteristics (Factors 1−3 quartiles) were detected.

Tests of multiplicative interactions between obesity and neighborhood SES, family structure, and housing characteristics with respect to the odds of multiple stone risk factors and multiple dietary factors did not show statistical significance, with the exception of one: the interaction between obesity and the most disadvantaged (Quartile 4) neighborhood housing characteristics was associated with lower odds of multiple dietary factors than the interaction between obesity and the least disadvantaged (Quartile 1) neighborhood housing characteristics (Appendix Table 4, available online).

Figure 1 reports the odds of multiple stone risk factors and multiple dietary factors stratified by obesity and neighborhood SES, family structure, and housing characteristics. Patients with obesity frequently had higher odds of multiple stone risk factors and multiple dietary factors than those without obesity. However, for patients with and without obesity, a consistent increase or decrease in the odds of multiple stone risk factors and multiple dietary factors with increasing neighborhood disadvantage was not observed.

In total, 626 of 1,264 (49.5%) patients met the criteria for secondary analysis in which patients without at least 1 appropriate 24-hour urine Cr were excluded, as defined by Litholink cutoffs. Individual and neighborhood characteristics of the secondary analytic sample are listed in Appendix Table 5 (available online). Multivariable logistic regression models assessing the associations of neighborhood SES, family structure, and housing characteristics with the 2 outcomes of interest are listed in Appendix Table 6 (available online). Black patients had lower odds of multiple stone risk factors than White patients, patients with obesity had higher odds of multiple stone risk factors than those without obesity, and patients with the most disadvantaged neighborhood SES (Quartiles 3 and 4) had higher odds of multiple stone risk factors than those with the least disadvantaged neighborhood SES (Quartile 1). For the second outcome, patients who were married had

Table 3. Odds of Multiple Stone Risk Factors and Multiple Dietary Factors for the Study Sample (N=1,264)

Characteristics	Multiple stone risk factors, OR (95% CI)	Multiple dietary factors, OR (95% CI)
Age, years		
18–34	ref	ref
35–49	0.49 (0.27, 0.86)	1.04 (0.72, 1.51)
50–64	0.58 (0.33, 1.02)	1.16 (0.81, 1.66)
≥65	0.58 (0.32, 1.07)	0.97 (0.65, 1.44)
Male	0.90 (0.66, 1.24)	1.21 (0.96, 1.52)
Married	0.81 (0.58, 1.14)	0.64 (0.50, 0.81)
Race		
White	ref	ref
Black	0.53 (0.31, 0.92)	0.77 (0.50, 1.18)
Other or unknown	1.48 (0.83, 2.65)	1.14 (0.79, 1.66)
Obese	1.61 (1.15, 2.26)	1.33 (1.06, 1.67)
Chronic kidney disease	0.82 (0.57, 1.18)	0.89 (0.68, 1.16)
Diabetes	0.90 (0.54, 1.52)	1.14 (0.78, 1.66)
Hypertension	1.28 (0.85, 1.91)	0.82 (0.61, 1.09)
SES (Factor 1)		
1st quartile (least disadvantaged)	ref	ref
2nd quartile	1.14 (0.75, 1.72)	1.06 (0.77, 1.45)
3rd quartile	1.43 (0.93, 2.21)	1.33 (0.97, 1.83)
4th quartile (most disadvantaged)	1.32 (0.86, 2.03)	1.16 (0.85, 1.59)
Family structure (Factor 2)		
1st quartile (least disadvantaged)	ref	ref
2nd quartile	1.09 (0.72, 1.66)	0.88 (0.64, 1.20)
3rd quartile	1.15 (0.75, 1.75)	1.00 (0.73, 1.37)
4th quartile (most disadvantaged)	1.39 (0.89, 2.16)	0.78 (0.57, 1.07)
Housing characteristics (Factor 3)		
1st quartile (least disadvantaged)	ref	ref
2nd quartile	1.06 (0.68, 1.64)	0.94 (0.69, 1.28)
3rd quartile	0.89 (0.58, 1.36)	0.79 (0.57, 1.07)
4th quartile (most disadvantaged)	1.01 (0.65, 1.56)	0.76 (0.55, 1.03)

Note: Ethnicity is not included as a covariate owing to a limited number of Hispanic patients in the data set (1.0%). Predominant stone composition is not included as a covariate owing to the majority of patients with unknown predominant stone composition (69.2%).

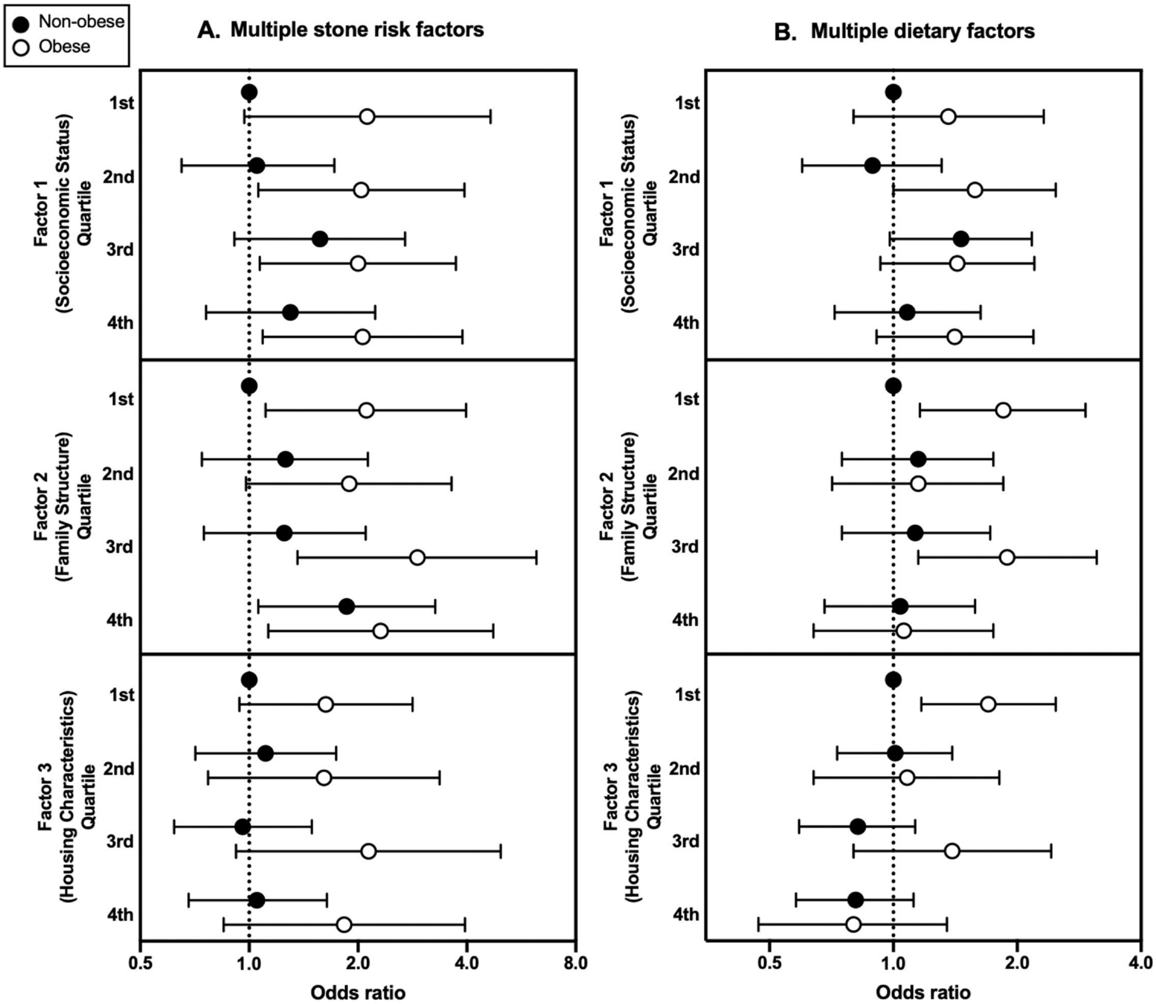

Figure 1. Odds of multiple stone risk factors and multiple dietary factors by obesity and quartiles of neighborhood factors for the study sample (N=1,264).

Note: Error bars indicate 95% CIs. Models adjusted for age, sex, marital status, race, chronic kidney disease, diabetes, and hypertension. The first quartile corresponds to the least disadvantaged group, and the fourth quartile corresponds to the most disadvantaged group.

lower odds of multiple dietary factors, and patients with obesity had higher odds of multiple dietary factors. The 2 tests of multiplicative interactions between obesity and neighborhood SES, family structure, and housing characteristics with respect to the odds of the 2 outcomes of interest showed statistical significance: the interaction between obesity and the second quartile of neighborhood family structure (Factor 2) was associated with lower odds of multiple stone risk factors than the interaction between obesity and the least disadvantaged (first) quartile (Appendix Table 7, available online), and the interaction between obesity and the second quartile of neighborhood housing characteristics (Factor 3) was associated with lower odds of multiple stone risk factors than the interaction between obesity and the least disadvantaged (first) quartile (Appendix Table 7, available online).

Appendix Figures 4 and 5 (available online) report the odds of multiple stone risk factors and multiple dietary factors, respectively, stratified by obesity and neighborhood SES, family structure, and housing characteristics, in quartiles. Patients with obesity frequently had higher odds of multiple stone risk factors and multiple dietary factors than patients without obesity in the least disadvantaged (first) quartile; however, for patients with and without obesity, a consistent increase or decrease in odds with increasing neighborhood disadvantage was not observed.

DISCUSSION

This study evaluated the extent to which obesity and neighborhood characteristics contribute to urinary risk factors for KSD. In a sample of 1,264 adult patients with

KSD who completed a 24-hour urine collection, 3 linearly independent neighborhood factors were identified: SES, family structure, and housing characteristics. Patients with obesity had increased odds of both multiple stone risk factors and multiple dietary factors. These associations with obesity persisted on a secondary analysis using more stringent urine Cr cutoffs to define an adequate 24-hour urine collection. Although no differences were observed in the odds of these outcomes across the levels of neighborhood SES, family structure, or housing characteristics in the primary analysis, there were increased odds of multiple stone risk factors in the third and fourth quartiles of SES (i.e., the most disadvantaged half of the sample) in the secondary analysis. In addition, consistent significant multiplicative interactions between obesity and the levels of neighborhood SES, family structure, or housing characteristics with respect to the outcomes of interest were not observed. In analyses stratified by obesity, patients with obesity frequently had higher odds of multiple stone risk factors and dietary factors, which is expected on the basis of the findings of the unstratified analysis mentioned earlier. Nonetheless, these odds did not consistently increase or decrease with increasing disadvantage in neighborhood SES, family structure, or housing characteristics. These results suggest that obesity is associated with urinary risk factors for stone disease, but the magnitude and strength of this association do not necessarily vary by levels of neighborhood disadvantage.

The rising prevalence of KSD parallels the rising prevalence of obesity. An analysis of the National Health and Nutrition Examination Survey showed that individuals with obesity had increased odds of self-reported KSD compared with individuals with normal BMI.[1] Obesity is also associated with abnormal urinary stone risk parameters in stone formers. For example, Eisner et al. performed an analysis of 880 patients evaluated at a metabolic stone clinic and found that higher BMI was associated with higher urine sodium and lower urine pH in men as well as higher urine uric acid and sodium and lower urine citrate in women.[14] The results of this study support those of previous work showing increased risk of urinary abnormalities among stone formers with obesity.

Few studies have focused on the relationships between sociodemographic factors and urinary abnormalities among stone formers. A recent assessment of the associations between the Distressed Communities Index and 24-hour urine results found that higher Distressed Communities Index (i.e., lower SES) correlated with lower urine citrate and potassium, suggesting lower intake of fruits and vegetables.[5] In an analysis of 435 patients from 2 stone clinics using neighborhood data, increasing poverty level and decreasing education level were both associated with significant increases in urine calcium excretion.[6] A subsequent evaluation of patients from the same clinics showed that those with state-assisted insurance had significantly higher urine sodium and pH than those with private insurance.[7] Consistent with these findings, this study identified an inverse correlation between neighborhood SES and urine sodium, which may reflect the differences in sodium intake, a modifiable dietary factor.

The relationship between SES and obesity is multifactorial.[9] For example, a recent analysis of the National Health and Nutrition Examination Survey found that neighborhood SES was positively associated with healthy body weight in women but not in men.[15] Other factors such as psychosocial stress may also play a significant role.[16] To the authors' knowledge, this is the first study to examine the joint influence of obesity and neighborhood characteristics on urinary stone risk parameters among stone formers. Owing to the numerous neighborhood characteristics relevant to the outcomes of interest in this analysis, a PCA was performed to reduce dimensionality. The development and evaluation of multifactorial neighborhood variables specific to the patient sample rather than the use of a single index of neighborhood disadvantage is a strength of this study. Although 2 dichotomous outcome variables were defined, 24-hour urine results should also be assessed as continuous variables; thus, an exploratory analysis was performed using linear regression with a conservative correction for multiple testing. Finally, analyses were repeated in a secondary sample of patients meeting more stringent 24-hour urine Cr cutoffs. The results of the primary and secondary analyses were comparable notwithstanding the 2 new statistically significant interaction terms for obesity with family structure and housing characteristics, which were present for only the second quartile compared with that for the first quartile (least disadvantaged) but not for the more disadvantaged third and fourth quartiles.

This study has several important implications for secondary prevention of KSD. First, urinary risk factors for KSD are present throughout all neighborhood strata, emphasizing the need for enhanced access to guideline-based[3] evaluation and management, especially for disadvantaged groups. Second, obesity is likely associated with urinary risk factors across all sociodemographic groups; thus, weight loss could be a worthwhile preventive measure for many stone formers, although further research is needed to confirm this. Third, contributors to urinary risk factors may still differ between neighborhood strata owing to variables not accounted for in this study; examples include household food insecurity[17] and neighborhood walkability.[18] Studies assessing whether community-level improvements in these environmental factors alter biological responses, such as urinary stone risk parameters, are needed.

Limitations

This study has several limitations. The patients included in the analytic sample resided in the southeast U.S. and were evaluated at an academic medical center. Furthermore, previous studies have shown that patients with KSD and low SES are less likely to complete 24-hour urine evaluation, suggesting a selection bias.[19] Therefore, the results of this study may not be generalizable to other geographic regions, other clinical settings, or the population as a whole. Neighborhood characteristics do not always accurately reflect individual characteristics[20]; however, relevant individual-level sociodemographic variables were also included in analyses, including age, sex, marital status, race, and ethnicity. Residual confounding is possible given the observational nature of this study, although numerous covariates relevant to KSD were accounted for, and patients with conditions associated with gastrointestinal malabsorption were excluded. In the study sample, 16.2% of patients had BMI measurements and 24-hour urine results separated by >1 year; the impact of temporal changes in diet and body weight is unclear for these patients. Medication use was not accounted for in the analyses, but each patient's first adequate 24-hour urine collection was used, so pharmacotherapy for KSD is less likely to have been introduced. Covariates such as chronic kidney disease, diabetes, and hypertension were captured using the International Classification of Diseases, Ninth Revision/ICD-10 codes, which are not always appropriately included in the electronic medical record. Although residential address and the corresponding Census tract identifier were available for most patients, the charted address at the time of this analysis (2021) and American Community Survey data from 2017 were used, either of which could be discordant with the patient's address at the time of the 24-hour urine collection. Finally, a larger study sample would have resulted in greater statistical power to detect the associations between the predictors and outcomes of interest in this study, particularly in the secondary analysis. Further evaluation of obesity, SES, and urinary stone risk factors within multi-institutional data sets or large prospective cohort studies may be practical approaches to achieve a larger sample size.

CONCLUSIONS

Among patients with KSD completing a 24-hour urine collection, obesity was independently associated with the presence of multiple stone risk factors and multiple dietary factors; however, the strength and magnitude of these associations did not vary significantly across sociodemographic groups defined by neighborhood variables.

ACKNOWLEDGMENTS

The authors thank Shirley Zhang, Lauren Oliver, and Lakshmi Subramani for reviewing the charts to determine stone composition; John Hollingsworth, Ryan Hsi, and Phyllis Yan for providing diagnosis and procedure codes for conditions associated with gastrointestinal malabsorption; and John Asplin for valuable input on study design and results reporting. In addition, the authors are grateful to the University of Alabama at Birmingham Obesity Health Disparities Research Center (NIH U54MD000502) and the Guest Editors for the opportunity to submit this work.

The research presented in this paper is that of the authors and does not reflect the official policy of the NIH. The IRB at the University of Alabama at Birmingham approved this study (protocol number 300006901).

Biostatistical consultation (DTR) was supported by the University of Alabama at Birmingham Center for Clinical and Translational Science (NIH UL1TR003096). Funding was also provided through NIH K08DK115833 (KDW) and P20DK128160 (DGA).

KDW reports conflicts of interest for Alnylam Pharmaceuticals and Steris Healthcare. No other financial disclosures were reported.

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SUPPLEMENTAL MATERIAL

Supplemental materials associated with this article can be found in the online version at https://doi.org/10.1016/j.amepre.2022.01.033.

SUPPLEMENT NOTE

This article is part of a supplement entitled Obesity-Related Health Disparities: Addressing the Complex Contributors, which is sponsored by the National Institute on Minority Health and Health Disparities (NIMHD), National Institutes of Health (NIH), U.S. Department of Health and Human Services (HHS). The findings and conclusions in this article are those of the authors

and do not necessarily represent the official position of NIMHD, NIH, or HHS.

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