Assessing the Psychometric and Ecometric Properties of Neighborhood Scales in Developing Countries: Saúde em Beagá Study, Belo Horizonte, Brazil, 2008–2009

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ABSTRACT *Although specific measurement instruments are necessary to better understand the relationship between features of neighborhoods and health, very few studies have developed instruments to measure neighborhood features in developing countries. The objective of the study was to develop valid and reliable measures of neighborhood context useful in a Latin American urban context, assess their psychometric and ecometric properties, and examine individual and neighborhood-level predictors of these measures. We analyzed data from a multistage household survey (2008–2009) conducted in Belo Horizonte City by the Observatory for Urban Health. One adult in each household was selected to answer a questionnaire that included scales to measure neighborhood domains. Census tracts were used to proxy neighborhoods. Internal consistency was evaluated by Cronbach's alpha, and multilevel models were used to estimate ecometric properties and to estimate associations of neighborhood measures with socioeconomic indicators. The final sample comprised 4048 survey respondents representing 149 census tracts. We assessed ten neighborhood environment dimensions: public services, aesthetic quality, walking environment, safety, violence, social cohesion, neighborhood participation, neighborhood physical disorder, neighborhood social disorder, and neighborhood problems. Cronbach's alpha coefficients ranged from 0.53 to 0.83; intraneighborhood correlations ranged from 0.02 to 0.53, and neighborhood reliability varied from 0.76 to 0.99. Most scales were associated with individual and neighborhood socioeconomic predictors. Questionnaires can be used to reliably measure neighborhood contexts in developing countries.*

KEYWORDS *Epidemiologic methods, Psychometrics, Residence characteristics, Data collection, Self-report, Environment design, Censuses*

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INTRODUCTION

The effects of residential environments or neighborhoods on health have been one of the most important themes in urban health over the few years¹⁻⁶. Several studies have documented associations between different health outcomes and neighborhood characteristics, after accounting for differences in individual-level characteristics across neighborhoods. Such associations have been reported for a diversity of health outcomes including cardiovascular diseases⁷⁻⁹, mortality^{10,11}, mental health outcomes¹²⁻¹⁶, physical activity^{17,18}, and perceived health¹⁹, among others²⁰⁻²².

Many studies have used census-based indicators, constructed by aggregating the socioeconomic characteristics of residents as proxies for the more specific neighborhood features hypothesized to be relevant to health. Although useful, the use of census information has important limitations, chiefly the difficulty in making causal inferences about neighborhood effects on health from analyses based on these measures due to residual confounding and extrapolations beyond the data²³. Another limitation is that in some circumstances neighborhood socioeconomic characteristics may be poor proxies for the neighborhood features of interest, resulting in incorrect inferences^{23,24}.

In an effort to move from crude proxies to measures of specific neighborhood level attributes, a number of measurement strategies have been proposed to characterize neighborhood physical and social environments including the availability and access to resources and social services as well as safety, social capital, and social cohesion, among others.²³⁻²⁵ One such approach is the use of systematic social observation (SSO) of the area of study to measure the physical and social attributes that are not reliably and validly captured by census information or other available data^{26,27}. Another technique that has been useful is the use of geographic information system (GIS) to construct measures of neighborhood availability and accessibility of a variety of resources²⁸⁻³⁰.

In addition, several studies have used information on individual perceptions of neighborhood conditions obtained from questionnaires administered to local residents to analyze the relationship with health outcomes in developed countries^{14,22-25}. The use of surveys is often an efficient way to characterize neighborhood conditions when sampling is dense enough to aggregate respondents across neighborhoods using appropriate methods^{23,31,32}. This aggregation process over individual's perceptions may result in a more valid measure of the neighborhood conditions and allows the assessments of constructs like social cohesion which cannot be measured using GIS or systematic social observation²³.

However, the construction of reliable and valid measures requires the assessment of their psychometric and ecometric properties. The psychometric properties—the extent to which the questionnaire items reliably capture an individual-level construct—can be assessed by analyzing the internal consistency and test-retest reliability. On the other hand, the ecometric properties—the extent to which the neighborhood means reliably capture a neighborhood-level construct—can be assessed using the three-level multilevel models and measuring the intraneighborhood correlation coefficient (ICC) and neighborhood reliability³.

Although several studies have reported the development of instruments to measure neighborhood features in developed countries^{14,22-24,31,32}, very few studies have examined these measures in developing countries. To our knowledge no studies have evaluated the psychometric and ecometric properties of neighborhood scales in a Latin American context^{33,34}.

The objectives of this work were a) to develop valid and reliable measures of neighborhood context useful in a Latin American urban context, b) to assess the psychometric and econometric properties of these measures, c) to examine individual and neighborhood-level predictors of these measures, and d) to generate neighborhood-level scores for use in further analyses.

METHODS

Study Population, Study Questionnaire, and Data

Data were collected from a cross-sectional survey conducted in Belo Horizonte City, Brazil, by the Observatory for Urban Health, in 2008–2009. The survey was conducted in two of the nine Sanitary Health Districts of Belo Horizonte, Barreiro and West districts, with a population of about 250,000 persons each and a total geographic area of 33.16 km².

The sample was selected using a stratified three-stage cluster sampling, including census tracts as the first level, households as the second, and residents as the third level. The sample strata were defined according to the Health Vulnerability Index (HVI)^{35,36}, an index created by combining social, demographic, economic, and health indicators from different sources for each census tract. Census tracts are defined by the Brazilian Census Bureau and include an average of 1,000 residents each.

In the first stage, 150 census tracts were selected from the total of 588 tracts in the sampling frame. These 150 census tracts contained a total of 6,493 eligible households. After deleting vacant lots, institutional and commercial buildings, and those who were not found after three attempts, 5436 households remained eligible. The refusal rate was about 25.0 %, resulting in a study sample of 4,051 households. In the third stage, one adult resident aged 18 years or older was selected to participate within each sampled household.

In a total, 4,051 adults answered the questionnaire. The survey was conducted by trained interviewers who visited the sampled households to administer the questionnaires and perform measurements. All instruments were tested, and all interviewers took part in centralized training activities.

The questionnaire was composed of six modules: household information, sociodemographic data, health, habits and behaviors, anthropometric evaluation, and social determinants. For the present study, we used information from the social determinants module to construct scales that represent selected features of neighborhood, using individual responses to items related to evaluation of public services, social disorganization, perception of neighborhood aesthetic quality, social participation, social capital, and violence. For most questions, the responses were “yes” or “no”. For some scales (e.g. public services) the items had response options ranging from 1 to 4 (1=very good, 2=good, 3=bad, 4=very bad).

We used census tracts as proxies for neighborhoods.

Statistical Analysis

The first step was to create the scales by selecting the items to compose each one on the basis of a conceptual model and prior work^{6,23,24,36}. We identified ten scales, representing different dimensions of neighborhood. Selected items were recoded by reversing the coding so that all items within each neighborhood dimension were coded in the same direction. After this recoding process, higher score values indicate

better scores for positive scales (e.g. aesthetic quality) and worse scores for negative scales (e.g. violence).

Second, the psychometric properties of each scale were assessed using the Cronbach's alpha coefficient. We started with ten domains, including a total of 84 items grouped together based on face value and previous work. We examined the change in the Cronbach's alpha after eliminating each of the items one at a time. When dropping an item did not change or decreased the value of the Cronbach's alpha, the item was dropped from the scale. In order to confirm the items in scales, we ran factor analyses of all items using the orthogonal and varimax rotation methods³⁷. We also estimated the correlations between the scale scores, using Pearson's correlation coefficient.

The next step was to assess the econometric properties of each neighborhood domain using three-level models^{3,23}. The level 1 model (item responses within individuals) modeled individual responses (i) for person (j) in neighborhood (k). In the level 2 model (persons within neighborhoods), the estimated mean scale for person (j) in neighborhood (k) was modeled as a function of a neighborhood mean and a person-specific deviation. The level 3 model (neighborhoods) estimated the neighborhood-specific mean as a function of an overall mean and a neighborhood-specific deviation. The level 1 error and the levels 2 and 3 random effects were assumed to be normally distributed. For more details see Muhajid (2007)²³.

Based on the models described above, the intraneighborhood correlation coefficient (ICC) was calculated as the ratio of the variance between neighborhoods divided by the sum of between- and within-neighborhood variances. The ICC ranges from 0 to 1, with the higher value indicating greater agreement between respondents within a neighborhood. It allows quantification of the percentage of variability in the scale score that lies between neighborhoods^{3,23}.

Also, we calculated the reliability of the neighborhood-level measure which is a function of the ICC and the number of participants in each neighborhood. This measure is calculated as a ratio of the "true" score variance to the observed score variance in the sample neighborhood mean. The values range from 0 to 1, where 1 represents the higher reliability indicating either that the neighborhood mean varied substantially across neighborhoods or the sample size per neighborhood was large^{3,23}.

To examine the predictors of neighborhood scales, we added level 2 (individual level) and level 3 (neighborhood levels) predictors to the three-level models described above. The individual-level covariates were age, sex, race, education, income, and residence time in the same neighborhood. Age and length of residence in the neighborhood were scaled by 10 years and were used as continuous. Race was classified as white, black, mulato, and Indigenous/Asian, based on self-report of participants.

The educational level (in years of schooling) was classified as ≤ 8 years (fundamental school) and > 8 years (more than fundamental school). The monthly household income was classified into three categories, considering the minimum Brazilian wage (about US \$290.00): less than two, from two to less than five, and five and more minimum Brazilian wages.

In order to assess the convergent validity (e.g. the extent to which measures were associated with other neighborhood features in the expected direction), we examined correlations between the various neighborhood scales as well as associations of the neighborhood scales with a neighborhood level (census tract) variable selected from the Brazilian Census (IBGE, 2000): the mean schooling for the household head (in years). The percentage of between-neighborhood variability in the scores explained by the Census variable was calculated as the between-neighborhood variance of the model with the individual covariates minus the between-neighborhood variance of the model

that included both individual-level and neighborhood variables, divided by the between-neighborhood variance of the first model.

Finally, we generated empirical Bayes estimates of mean values for each census tract for the ten domains proposed³⁸.

Data were weighed in all analyses to account for the sampling design and to correct for non-response, using the suites SVY and GLLAMM of Stata 11 software^{39,40}.

RESULTS

The final sample consisted of 4,048 survey respondents distributed in 149 census tracts. The number of people per tract ranged from six to 45 with a mean of 27.3 (± 7.2). One census tract was dropped because it had only three respondents. Over half of the respondents (54.1 %) were female, and the ages ranged from 18 to 95 years (mean 41.2; sd 16.4); 46.8 % were mulato, 39.6 % were white, and 13.0 % were black. With respect to socioeconomic measures, 37.2 % reported to have completed high school, 1.5 % had never attended school, and 45.4 % had monthly income between two and five minimum Brazilian wages (Table 1). The duration of residence in the neighborhood varied from 1 to 73 years (mean 15.8; sd 12.6).

Based on the theoretical model^{6,23,24,36}, we constructed ten neighborhood scales, representing the following domains: public services, aesthetic quality, walking environment, safety, violence, social cohesion, neighborhood participation, neighborhood physical disorder, neighborhood social disorder, and neighborhood problems. Initial analyses began with 84 items grouped into ten domains. After preliminary analysis based on Cronbach's alpha value, one domain (stress) was eliminated due to poor reliability (Cronbach's alpha 0.23), and 12 items were removed from the scales to increase their internal consistency. The original numbers of items in each scale were nine (public services), nine (aesthetic quality), nine (walking environment), three (safety), six (violence), six (social cohesion), 11 (neighborhood participation), eight (physical disorders), six (social disorders), and 17 (neighborhood problems). The dropped items

TABLE 1 Descriptive statistics of selected variables from Saúde em Beagá, 2008–2009

	Number	Percent
Gender		
Male	1,659	45.9
Female	2,389	54.1
Race ^a		
White	1,541	39.6
Black	525	13.0
Indigenous/Asian	36	0.6
Parda	1,928	46.8
Schooling (years) ^b		
≤8	1,820	45.0
>8	2,226	55.0
Monthly income (in Brazilian minimum salary) ^c		
Less than 2	1,056	26.7
2 to less than 5	1,811	45.5
5 and more	643	18.8

^a18 missing

^bTwo missing

^c98 missing

were distributed as follows: public services (one), aesthetic quality (five), walking environment (two), safety (one), social disorders (two), and neighborhood problems (one). Exploratory factor analysis yielded scales similar to those identified a priori based on face value and prior work. The final composition of scales is shown in Figure 1.

Descriptive statistics of the scales are shown in Table 2. The number of items in each scale ranged from two (safety) to 16 (neighborhood problems). The Cronbach’s alpha coefficient ranged from 0.51 (walking environment) to 0.83 (neighborhood participation), demonstrating moderate to good internal consistency.

Correlations between the ten scales indicated good convergent validity, with correlations being in the expected directions. For example, the neighborhood problems scale was positively correlated with violence (0.776), social disorder (0.720), and physical disorder (0.657) and was negatively correlated with public services (−0.369), aesthetic quality (−0.472), and walking environment (−0.248).

The ecometric properties of all scales are shown in Table 3. Using the information in the first three rows, we calculated the ICC (forth row), which ranged from 0.02 (social cohesion) to 0.33 (walking environment). The scales of social cohesion, neighborhood problems, and activities with neighbors showed lower values of ICC compared with the others. For most scales the neighborhood-level reliability (fifth row) was high (more than 0.93), with the exception of the social cohesion scale which presented the lowest reliability (0.76).

The models that included individual-level variables are shown in Table 4.

Neighborhood characteristics were associated with individual-level variables. Being older was associated with reports of higher scores on public services and aesthetic quality (better public services and aesthetic quality) and with lower scores on violence (less violence), and physical and social disorder and problems (lower levels of disorder and problems). Women reported significantly lower scores (e.g. worse levels) for public services, aesthetic quality, and walking environment. They

FIGURE 1. Description of neighborhood scales items, Saúde em Beagá, 2008–2009.

TABLE 2 Descriptive statistics for ten scales on neighborhood conditions, Saúde em Beagá, Belo Horizonte, Brazil, 2008–2009 (*n* = 4051)

	No. of subjects	Initial no. of items in scale	Final no. of items in scale	Range of scores	Minimum score	Maximum score	Mean score	Standard deviation	Cronbach's alpha
Services	4,041	9	8	1–4	1.68	3.52	2.58	0.36	0.65
Aesthetic quality	4,035	9	4	1–4	1.19	3.94	2.96	0.97	0.60
Walking environment	4,040	9	7	1–4	1.87	3.64	3.24	0.43	0.51
Safety	4,013	3	2	1–4	1.14	3.92	2.97	1.16	0.53
Violence	4,045	6	6	1–4	1.05	3.77	1.99	0.84	0.70
Social cohesion	4,030	6	6	1–4	1.11	3.98	3.29	0.81	0.76
Neighborhood participation	3,663	11	11	1–4	1.07	3.97	2.76	0.82	0.83
Physical disorder	3,979	8	8	1–4	1.16	3.69	2.11	0.82	0.62
Social disorder	3,929	6	6	1–4	1.09	3.87	2.27	0.87	0.74
Neighborhood problems	4,035	17	16	1–4	1.27	3.49	2.28	0.57	0.73

TABLE 3 Variance components, intraneighborhood correlation coefficients, and neighborhood-level reliability for ten scales on neighborhood conditions, Saúde em Beagá, Belo Horizonte, Brazil, 2008–2009 (n=4051)

	Services	Aesthetic quality	Walking environment	Safety	Violence	Social cohesion	Neighborhood participation	Physical disorder	Social disorder	Neighborhood problems
Within-person variance	0.42	1.40	1.16	1.18	1.50	1.11	1.58	1.53	1.53	1.53
Within-neighborhood variance	0.06	0.41	0.06	0.69	0.36	0.50	0.48	0.25	0.56	0.18
Between-neighborhood variance	0.01	0.14	0.03	0.08	0.04	0.01	0.05	0.04	0.09	0.02
Intraneighborhood correlation	0.16	0.25	0.33	0.10	0.11	0.02	0.09	0.14	0.13	0.08
Neighborhood reliability	0.95	0.98	0.98	0.94	0.94	0.76	0.93	0.91	0.96	0.93

TABLE 4 Mean difference in neighborhood scale scores according to individual-level variables, Saúde em Beagá, 2008–2009^a

	Services	Aesthetic quality	Walking environment	Safety	Violence	Social cohesion	Neighborhood participation	Physical disorder	Social disorder	Neighborhood problems
Age (per 10 years)	0.009 (0.004) ^b	0.056 (0.010)**	−0.009 (0.005)	−0.021 (0.013)	−0.088 (0.009)**	−0.045 (0.010)**	−0.004 (0.009)	−0.075 (0.007)**	−0.107 (0.012)**	−0.061 (0.005)**
Gender										
Male ^c										
Female	−0.048 (0.011)***	−0.101 (0.029)**	−0.083 (0.015)**	0.295 (0.038)**	0.148 (0.026)**	0.015 (0.028)	−0.015 (0.027)	0.039 (0.022)	−0.022 (0.033)	0.081 (0.018)**
Race										
White ^c										
Black	0.031 (0.018)	0.073 (0.047)	0.055 (0.023)*	−0.128 (0.060)*	−0.042 (0.042)	−0.011 (0.045)	0.071 (0.044)	−0.035 (0.035)	−0.042 (0.053)	−0.044 (0.028)
Indigenous/Asian	−0.034 (0.059)	−0.118 (0.150)	−0.011 (0.075)	0.175 (0.195)	0.066 (0.136)	−0.108 (0.144)	−0.092 (0.141)	0.044 (0.113)	−0.050 (0.171)	0.015 (0.092)
Mulatto	0.025 (0.012)*	−0.001 (0.032)	0.023 (0.016)	−0.034 (0.041)	−0.019 (0.029)	0.009 (0.030)	0.035 (0.030)	−0.021 (0.024)	−0.002 (0.036)	−0.022 (0.019)
Schooling (years)										
>8 ^c										
≤8	−0.064 (0.013)**	0.113 (0.034)**	0.021 (0.017)	−0.110 (0.043)*	−0.050 (0.030)	0.002 (0.031)	0.003 (0.031)	−0.115 (0.025)**	−0.023 (0.038)	−0.051 (0.020)*
Monthly income ^d										
5 and more ^c										
2 to less than 5	−0.014 (0.014)	0.027 (0.037)	0.010 (0.019)	−0.080 (0.047)	0.013 (0.033)	−0.032 (0.035)	−0.038 (0.035)	−0.051 (0.027)	−0.019 (0.042)	−0.013 (0.022)
Less than 2	−0.003 (0.017)	−0.030 (0.045)	0.015 (0.022)	−0.080 (0.058)	−0.040 (0.040)	−0.163 (0.042)**	−0.114 (0.042)**	−0.018 (0.033)	−0.069 (0.051)	−0.027 (0.027)
Time in neighborhood (per 10 years)	−0.001 (0.005)	0.026 (0.012)*	0.006 (0.006)	0.036 (0.016)*	0.027 (0.011)*	0.071 (0.011)**	0.024 (0.015)*	−0.007 (0.052)	0.032 (0.014)*	0.016 (0.007)*

*P<0.05; **P<0.01
^aDerived from a three-level multilevel model
^bNumbers in parentheses, standard error
^cReference category
^dBrazilian minimum wage (about US \$290.00)

also reported higher scores for safety, violence, and neighborhood problems (more safety but also more violence and more problems) than men. Mulato participants reported higher scores than whites (better scores) on public services, and black participants reported higher scores than whites (better) on walking environment and lower scores (worse) on safety.

Regarding schooling, the associations differed according to the domains. Compared with those who had more than 8 years of schooling, the less educated reported higher scores for aesthetic quality and lower scores for public services, safety, physical disorder, and neighborhood problems. Lower-income (less than two minimum wages) respondents reported lower scores on social cohesion and neighborhood participation compared to high-income respondents.

Longer duration of residence in the same neighborhood was associated with reports of higher scores (e.g. better) on aesthetic quality, safety, social cohesion, and neighborhood participation. In contrast, longer residence in the neighborhood was also associated with higher scores (worse) on violence, social disorders, and neighborhood problems.

After controlling for individual-level variables, higher neighborhood education was associated with lower scores on walking environment, violence, neighborhood participation, physical disorder, social disorder and neighborhood problems. Neighborhood education explained considerable amounts of between-neighborhood variability for aesthetic quality (22.3 %), violence (24.4 %), social disorder (34.1 %), and neighborhood problems (32.5 %) scales. For the neighborhood participation and physical disorder scales, the variability explained was 6.9 % and 11.0 %, respectively. For safety it was 2.4 %, and for social cohesion it was 1.8 %. In contrast, neighborhood education explained almost none of the between-neighborhood variability for walking environment (0.35 %) and public services (0.004 %) scales (Table 5).

DISCUSSION

To our knowledge, this is one of the first projects to construct measures of neighborhood characteristics using survey-based reports in a large Latin American city. Measures to assess different dimensions of neighborhood attributes were constructed, and their psychometric and ecometric properties were analyzed. Convergent validity was also analyzed by examining associations between the scales and by relating the scales to socioeconomic neighborhood indicators from census data.

We examined scales to measure ten neighborhood domains. In general, the scales showed moderate to good internal consistency (Cronbach's alpha ranging from 0.51 to 0.83). This was generally similar to the internal consistency reported in other studies conducted in the USA. A study conducted in New York City reported Cronbach's alphas coefficient ranging from 0.77 (safety from crime) to 0.91 (access to healthy food)²³. Another study using data of Multi-Ethnic Study of Atherosclerosis (MESA) from three different regions in the USA reported Cronbach's alphas ranging from 0.73 to 0.83²⁴.

Regarding the ecometric analysis, most of scales performed well, presenting good properties. The variability in the ICCs across the different domains, which ranged from 0.02 to 0.33, was consistent with values reported for other samples in the USA^{3,24}. The walking environment and aesthetic quality scales had the highest ICCs, 0.33 and 0.25, respectively. These scales clearly performed well, capturing

TABLE 5 Mean difference in neighborhood scale scores according to neighborhood variables, Saúde em Beagá, 2008–2009^a

	Services	Aesthetic quality	Walking environment	Safety	Violence	Social cohesion	Neighborhood participation	Physical disorder	Social disorder	Neighborhood problems
Mean years of education of household head (var_10)	0.00008 (0.00374)	0.06925 (0.01122)	−0.00438 (0.00565) **	−0.02106 (0.01149)	−0.0453035 (0.0075829) **	−0.00987 (0.00682)	−0.02589 (0.00854)**	−0.02914 (0.00717) **	−0.07067 (0.00996) **	−0.03142 (0.00484)**
Variance										
Individual variable	0.0099347	0.1415910	0.0286939	0.0805384	0.0398321	0.0109950	0.0487876	0.0406902	0.0879486	0.0148283
model										
Neighborhood variable	0.0099343	0.1100327	0.0285928	0.0785792	0.0301296	0.0107924	0.0454062	0.0362052	0.0579654	0.0100153
model										
Percentage of between-neighborhoods variance explained	0.004	22.3	0.35	2.4	24.4	1.8	6.9	11.0	34.1	32.5

^aDerived from a three-level multilevel model

variability in neighborhood characteristics. The services, physical disorder, social disorder, violence, and safety scales had intermediary values, with ICCs ranging from 0.16 to 0.10. However, three scales had very low ICCs despite having good Cronbach's alphas: neighborhood participation (0.02), neighborhood problems (0.08), and social cohesion (0.09). The low ICCs suggest that these scales are not adequately capturing neighborhood attributes. The reasons for the low ICCs for these three scales remain to be determined, but at least two of them (social cohesion and neighborhood participation) attempt to capture complex relationships among neighbors, which may have strong individual perceptual components resulting in low within-neighborhood correlations^{6,24,41}. The social cohesion and neighborhood participation scales involve more subjective perceptions, including questions about social relationships and political participation, that are not traditionally "discussed" by the population in Belo Horizonte and consequently may be more difficult to measure reliably.

In contrast, the scales that include more objective attributes like walking environment, aesthetic quality, and public services had the higher values of ICC, probably indicating that people are more easily able to evaluate these features for their neighborhood. Thus, there is less heterogeneity in responses from the same neighborhood resulting in higher ICCs. The other four scales—physical disorder, social disorder, violence, and safety—had intermediary values of ICC and are comprised of both objective and subjective questions.

The neighborhood reliability values ranged from 0.76 to 0.99, similar to studies in other countries^{3,14–16,23,24}. The moderate to high neighborhood reliabilities may indicate that the mean of scores are good estimators of the true neighborhood scores for each scale. However, in several cases reliabilities were high despite low ICCs due to the relatively large within-neighborhood sample size in our sample. For example, although social cohesion, neighborhood problems, and neighborhood participation scales showed low ICCs (0.02, 0.08, and 0.09, respectively), the neighborhood reliability of these scales was high (0.76, 0.99, and 0.93, respectively).

Correlation analyses showed evidence of good convergent validity. For example, neighborhood problems were positively correlated with violence (0.776) and physical disorder (0.657) and was negatively correlated with walking environment (−0.248). These results are also similar to those reported by studies described above^{23,24}.

In our data, there was some evidence of differences in reports associated with individual-level characteristics, including age, education, and income. Other studies have also documented variation in reports of neighborhood attributes based on individual-level characteristics²⁴. The models that included the individual-level variables showed interindividual differences in the reporting of neighborhood features associated with age, gender, race, schooling, income, and length of residency in neighborhood. For example, older people systematically reported higher levels of services and aesthetic quality and lower levels of violence, social cohesion, disorder, and problems. Some systematic differences were also observed by gender with women reporting worse services, aesthetic quality, and walking environments and more neighborhood problems and violence, but also higher scores on safety. Although some differences by education and income were observed, they were not always in a consistent direction. For example, low educated people were more likely to report worse services and safety, but better aesthetic quality and less physical disorder and neighborhood problems. Lower income was associated only with lower social cohesion and lower participation.

Differences in reports by individual-level characteristics within areas may reflect differences in perceptions as well as real heterogeneities in attributes within census tracts. As an example, low-income participants may live closer to areas with adverse environments than high-income participants within the same census tract⁶.

Neighborhood education derived from the 2000 Brazilian census showed associations with the scales and explained important portions of the between-neighborhood variability for some of the scales, including aesthetic quality, violence, social disorder, neighborhood problems, neighborhood participation, and physical disorder, although substantial between-neighborhood variability remained. However, the walking environment and public services scales were not associated with neighborhood education, and neighborhood education did not explain the variability between neighborhoods. Belo Horizonte is a typical urban center of Brazil, characterized by the contrast between poor areas adjacent to rich areas. This may influence the individual responses, because regardless of socioeconomic level, people may share some similar environments (e.g. walking environment) and services available for a broader area, resulting in similar perceptions across economically diverse adjacent neighborhoods. This suggests that the certain neighborhood characteristics may not be well proxied by census measures reinforcing the need of using specific measures in order to capture neighborhood features that may influence health conditions.

One possible limitation of our study pertains to the geographic area used to proxy “neighborhoods”—the census tract, an administrative definition, used as a proxy unit of neighborhood, as in previous studies^{9,12,15,42}. Large variability in the sizes of census tracts may cause more heterogeneity in answers, especially for those questions related to personal relationships. Moreover, the questions asked participants to refer to their neighborhood with no specific guidelines on how a neighborhood should be defined. A part of the within-neighborhood variability may therefore be attributable to different neighborhood definitions used by participants. Differences based on personal subjectivities as well as measurement error due to incomplete knowledge will also increase within-neighborhood variability. Other studies used different areas, like predefined distance in order to better capture variation in these dimensions over space^{15,23,24}. Despite limitations in using census tracts, an advantage is the possibility of linking data from several sources, such as government indicators, that are often available for census tracts^{4–6,23,24,27,42}. Survey measures may not completely capture neighborhood features of interest. Other techniques as social systematic observation and geographical information systems may also be of use^{6,14,24,32}.

Despite the complexity of these measures, our results showed that an important part of the variability in neighborhood scores occurred between census tracts, demonstrating the usefulness of the instrument proposed here to capture information not reflected in census indicators. The use of scales is based on underlying assumption that this aggregation process over individuals’ perceptions will result in a more valid measure of the objective attribute. Empirical Bayes estimation techniques that build on the three-level models we describe can take into account interindividual differences in responses to construct the aggregate measures.

Few studies have analyzed the econometric properties of neighborhood measures in developing countries, especially in Latin American urban contexts, although there is growing interest in using these kinds of measures^{3,14–16,23,24,33,34}. The findings of our study suggest that a broad set of neighborhood features can be measured using individual reports. Also, we demonstrated the feasibility of measuring constructs

using survey data and showed data supporting the validity and reliability of these measures. We also identified selected scales (the social cohesion, neighborhood participation, and neighborhood problems scales) that did not perform well in capturing between-neighborhood variability. New measures of these domains useful in contexts like ours may need to be developed. The other scales performed well and can be recommended for use in other studies linking neighborhood factors to health outcomes. This approach may be extended to other urban settings and can be used not only to study the health consequences of neighborhood features but also to evaluate the impact of neighborhood interventions aimed at changing some of these features.

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