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São Paulo urban health index: measuring and mapping health disparities

Índice de saúde urbana de São Paulo: medindo e mapeando disparidades em saúde

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ABSTRACT: ***Objective:*** To calculate and map the health inequalities in the city of São Paulo using the Urban Health Index (UHI) methodology. ***Methods:*** Seven indicators were selected from the Brazilian census: (1) proportion of households with access to sewage systems, (2) proportion of households served by regular waste collection, (3) proportion of households with two or more toilets, (4) proportion of households receiving tap water, (5) average income per household, (6) percentage of white people, and (7) literacy rate. Based on the UHI methodology, all health indicators were standardized and aggregated into a single metric at the census tract level. The UHI scores were ranked and plotted. The disparity ratio and the graph slope were calculated. The correlation between indicators was tested. Results were geocoded to produce a map of health risks. ***Results:*** The distribution of index values showed a linear middle section and deviations at each end. The disparity ratio found was 2.95, while the slope was 0.30. All indicators were significantly correlated. The map displayed a typical pattern of health inequality between the downtown and the periphery. The tracts located in the city's downtown had higher UHI values than those on the outskirts. ***Conclusions:*** The results of this study presented a visual distribution of health disparities in the city of São Paulo, proving to be a valuable method for identifying areas that require public health attention.

Keywords: Brazil. Geographic information systems. Social determinants of health. Public health.

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RESUMO: ***Objetivo*:** Calcular e mapear as desigualdades em saúde na cidade de São Paulo por meio da metodologia do índice de saúde urbana (UHI). ***Métodos*:** Sete indicadores foram selecionados do censo brasileiro: (1) proporção de domicílios com acesso a esgoto, (2) proporção de domicílios com coleta regular de lixo, (3) proporção de domicílios com dois ou mais banheiros, (4) proporção de domicílios que recebem água encanada, (5) renda média por domicílio, (6) porcentagem de pessoas brancas e (7) taxa de alfabetização. Usando a metodologia UHI, todos os indicadores de saúde foram padronizados e agregados em uma única métrica para o setor censitário. Os valores de UHI foram classificados e plotados. A razão de disparidade e a inclinação do gráfico foram calculadas. A correlação entre os indicadores foi testada. Os resultados foram geocodificados, produzindo um mapa de risco à saúde. ***Resultados*:** A distribuição dos valores do índice apresentou uma seção intermediária linear e desvios nas extremidades. A taxa de disparidade encontrada foi de 2,95, enquanto o coeficiente angular foi 0,30. Todos os indicadores apresentaram correlação significativa. O mapa exibiu um arranjo característico de desigualdade em saúde entre o centro e a periferia. Os setores localizados na região central da cidade apresentaram valores de UHI mais elevados do que os da periferia. ***Conclusão*:** Os resultados deste estudo apresentaram uma distribuição visual das disparidades de saúde na cidade de São Paulo, demonstrando ser um método valioso para a identificação de áreas que requerem atenção da saúde pública.

***Palavras-chave*:** Brasil. Sistemas de informação geográfica. Determinantes sociais da saúde. Saúde pública.

INTRODUCTION

Health can be affected by socioeconomic factors, including employment status, education, ethnicity, and income level. Health inequality is the difference in access to resources and factors that influence health, which can be changed by social contexts or public policies. It reflects not only disparities in income and wealth but also in how people have access to opportunities based on their ethnicity, gender, education, and geographical location, among others. The conditions in which people are born, work, live, and age are considered the main causes of health inequities. These conditions are known as "social determinants of health", a term that summarizes the social, economic, political, cultural, and environmental determinants of health[1].

Brazil is one of the world's most unequal countries, with over half of the country's wealth owned by the top 1% of the population[2]. São Paulo is the largest and most populous city in South America, with a population of over 12 million people, and despite being the wealthiest city in Brazil, it reflects the country's economic and social disparities[3]. The city's persistent income inequality is evident, as its Gini coefficient was 0.57 in 1991 and 0.58 in 2020, reaching 0.65 in 2010 (the Gini coefficient is a value from 0 to 1, with higher scores indicating greater inequality)[4]. São Paulo exhibits a wide range of incomes, from the typical poverty of developing countries to the wealth found in rich nations[5]. Health inequity results from these disparities, as illness and health follow a social gradient; the lower the socioeconomic position, the worse the health[1].

Policies to reduce these inequalities are necessary for the city of São Paulo. However, for public policies to be effective, evidence of health inequalities must be considered[6]. The poverty line is generally adopted as a measure of population inequality. Although helpful in terms of comparisons, this concept is controversial. It establishes the minimum income to survive, but does not consider other dimensions of poverty[7]. Thus, when measuring societal disparities, other dimensions besides income, such as education, health, and sanitation, must be considered for a comprehensive assessment of inequality[8]. This is particularly important for urban areas in developing countries, where welfare and social services are not universally distributed[9].

Many health indicators and health determinants can be used to measure the health of a population; however, interpreting this amount of information requires a great effort. Therefore, using a single metric that compiles these data is an interesting proposition that offers several advantages. Also, a tool that can identify the most vulnerable groups in a population would be of great importance in prioritizing public health interventions[10].

The Urban Health Index (UHI), proposed by the World Health Organization, is a single metric used to measure and map health disparities[10]. It is an absolute health measure that provides a basis for classifying urban areas and an instrument for planning and evaluating interventions[11]. The UHI method allows a free choice of indicators in its composition since, when formulated from the available indicators, it will not be highly sensitive to substitutions[10].

This study aimed to use the UHI methodology to calculate and map the health inequalities in the city of São Paulo. Health determinants were combined into a single metric for small census tracts, which were geocoded, producing a map of health risks. This work is the first part of a larger project seeking to quantify and map dental health disparities across Brazil.

METHODS

ETHICS

Ethics Exemption was obtained from the Ethics Committee of the University of Western Australia (RA/4/20/5733) since only previously collected, publicly available, anonymous data were used.

DATA

Social determinants of health at the census tract level were the basis for this study. The data used to build the indicators derived from the 2010 Brazilian Census. The census tract is the smallest area examined by the Brazilian Institute of Geography and Statistics (*Instituto Brasileiro de Geografia e Estatística* — IBGE) and has an average of 300 households. The municipality of São Paulo has five planning areas with 96 administrative districts and 18,363 census tracts[12].

Seven indicators were selected from 5 domains:

1. Sanitation: proportion of households with access to sewage systems, proportion of households served by regular waste collection, proportion of households with two or more toilets;
2. Water quality: proportion of households receiving tap water;

3. Income: average income per household;
4. Demographic: percentage of white people; and
5. Education: literacy rate. The selection of these indicators followed the recommendation of the World Health Organization and the availability of data from the Brazilian Census[1,12].

A total of 181 tracts (1% of all tracts), lacking one or more indicator values, were excluded from the study.

UHI CONSTRUCTION

The UHI methodology introduces a new measure of health inequality built on the same framework as the Human Development Index (HDI)[10].

STANDARDIZATION

The value of each indicator was transformed into a dimensionless proportion based on the distance from the minimum divided by the range. Thus, the health indicators were standardized according to the equation:

$$I^S = \frac{I - \min*\,(I)}{\max(I) - \min*\,(I)}$$

in which I was the observed indicator value, $max(I)$ was the maximum indicator value, $min^*(I)$ was the minimum indicator value minus a small constant (0.1), and I^s was the standardized indicator, which satisfied: $0<I^s\leq1$.

A small constant (0.1) was subtracted from the minimum indicator value to ensure that all standardized indicator values were greater than zero.

The standardization guaranteed that all indicators had the same logical type: range proportions, in which low values are undesirable, and higher values are desirable.

Amalgamation

A geometric mean was used to combine all standardized indicators into a single metric according to the equation:

$$UHI = \left(\prod_{i=1}^{j} I_i^S\right)^{\frac{1}{j}}$$

in which I^s was the standardized indicator, and the UHI was calculated by multiplying the 7 (j) standardized indicators together, then raising the product to the 7th (j^{th}) power.

CORRELATION AMONG INDICATORS

A Spearman correlation matrix was constructed to test the relationship between each of the standardized indicators.

ASSESSING DISPARITIES

To identify the inequalities across São Paulo, the census tracts were ranked according to their UHI scores. Abscissa UHI scores were then plotted against ordinate UHI values. The expected graph had a linear shape, with markedly deviant extremes based on previous UHI research[11].

Slope and disparity ratio were calculated using the graph. The disparity ratio was the ratio of the mean of the upper decile to the mean of the lower decile. It was used as a measure of the disparity between the best-off and the worst-off tracts in São Paulo.

The slope of the middle section (80% of the data) was also calculated using simple linear regression. It provided an appraisal of the heterogeneity extent across the tracts since a steep slope indicates a heterogeneous group, while a flat slope indicates uniformity in the middle section.

Visualization

Quantum Geographic Information System software (version 3.4) was used to display the UHI outcomes with different colors. UHI results were divided into ten quantile ranges, and a different hue was attributed to each census tract on the map depending on the UHI value. Darker hues were used to highlight tracts with lower UHI values and a higher risk of poor health. Shapefiles containing the census tracts of São Paulo were obtained from the IBGE[12].

RESULTS

The distribution of tract-level index values by their rank order demonstrated the usual UHI shape — a linear middle section with deviations at both ends (Figure 1). The ratio of the upper to the lower 10% of UHI distribution indicated the overall disparity between the best-off and the worst-off tracts. In contrast, the slope ratio of the middle 80% furnished the heterogeneity of the analyzed group. The distribution of the 18,182 census tracts revealed a high disparity ratio (2.95) and a moderate disparity slope (0.30). The percentage distribution of UHI showed that 67% of the population presented values below 0.50, and less than 1% of the tracts had scores higher than 0.75 (Figure 2).

The correlation matrix demonstrated a significant correlation between all indicators. They ranged from 0.148 (between the proportion of households with two or more toilets and the proportion of households receiving tap water) to 0.861 (between income and percentage of white people) (Table 1).

The UHI map of São Paulo displayed a characteristic pattern of health disparity between the city's downtown and its periphery (Figure 3). In general, downtown census tracts exhibited higher UHI values than those on the city's outskirts. However, peripheral tracts presented a higher variation in index values, which can be identified on the map, with a colorful periphery contrasted with a relatively monochromatic downtown.

Furthermore, the health risk increases outside the downtown, especially in the city's south area. This region has darker hues on the map, denoting a lower UHI value and greater health risk.

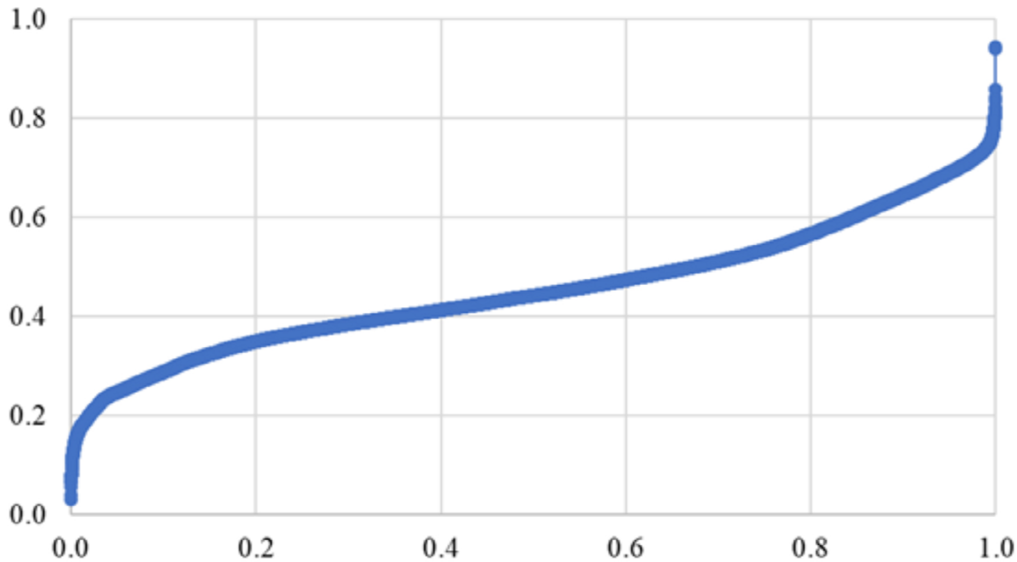

Figure 1. Urban health Index distribution of the 18,182 census tracts in São Paulo.

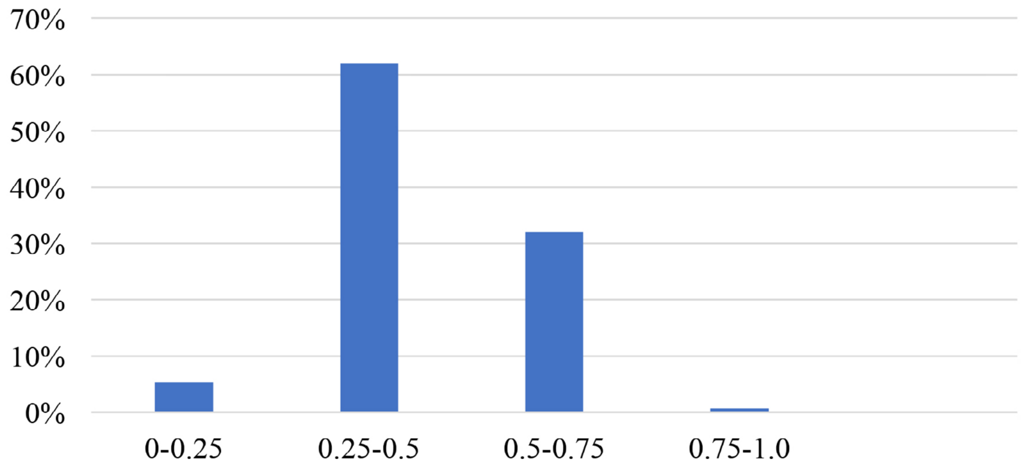

Figure 2. São Paulo urban health index distribution.

DISCUSSION

This paper intentionally chose to investigate the census tract because this approach more accurately reflects health inequities within urban areas. The reason is that disaggregated analyses preserve nuances and details of inequalities, whereas comprehensive estimates may hide important disparities[11,13,14]. The Brazilian census offers a wide range of population data; however, this study employed health determinants instead of health indicators, given the lack of health data available in micro-urban areas. This scenario demonstrates the necessity of comprehensive health data collection based on small areas.

The UHI method allows a free choice of indicators in its composition; in this study, health determinants were selected following the WHO recommendation[1] and the data available on the Brazilian Census. Although adequate for this paper, the selected indicators are not necessarily the best fit for other studies. Indicators such as gender, education level, age, and population density should be considered in further research.

The index plot for São Paulo displayed a linear middle section with markedly deviant ends (Figure 1), shape also manifested in previous studies[11,15]. The disparity ratio and slope were calculated to investigate the extent of variation in health risk for São Paulo. The disparity ratio (2.9) demonstrates a substantial inequality, while the slope of the middle section (0.3) suggests a heterogeneous population. Inequality measures based on unique proportions that consider only extreme groups, such as disparity ratio, may seem overly simplified, but they are easily understood by all types of audiences.

Also, most census tracts of São Paulo (67%) scored a UHI below 0.50 (Figure 2). Another study about social inclusion/exclusion showed congruent results, with two-thirds of the districts of São Paulo scoring below acceptable living standards[16]. Socioeconomic inequality has a destructive effect on society's health, as a higher prevalence of disease was found in socioeconomically disadvantaged areas[13]. Thus, the population from areas with lower UHI values is at greater risk of poor health.

Table 1. Spearman's correlation matrix.

	Income	Literacy	Ethnicity	Toilets	Sewage	Water	Waste
Income	1.000	0.787*	0.861*	0.709*	0.404*	0.232*	0.178*
Literacy	0.787*	1.000	0.775*	0.529*	0.435*	0.247*	0.195*
Ethnicity	0.861*	0.775*	1.000	0.668*	0.402*	0.218*	0.198*
Toilets	0.709*	0.529*	0.668*	1.000	0.238*	0.148*	0.180*
Sewage	0.404*	0.435*	0.402*	0.238*	1.000	0.383*	0.272*
Water	0.232*	0.247*	0.218*	0.148*	0.383*	1.000	0.244*
Waste	0.178*	0.195*	0.198*	0.180*	0.272*	0.244*	1.000

*Correlation is significant at the 0.01 level (2-tailed)

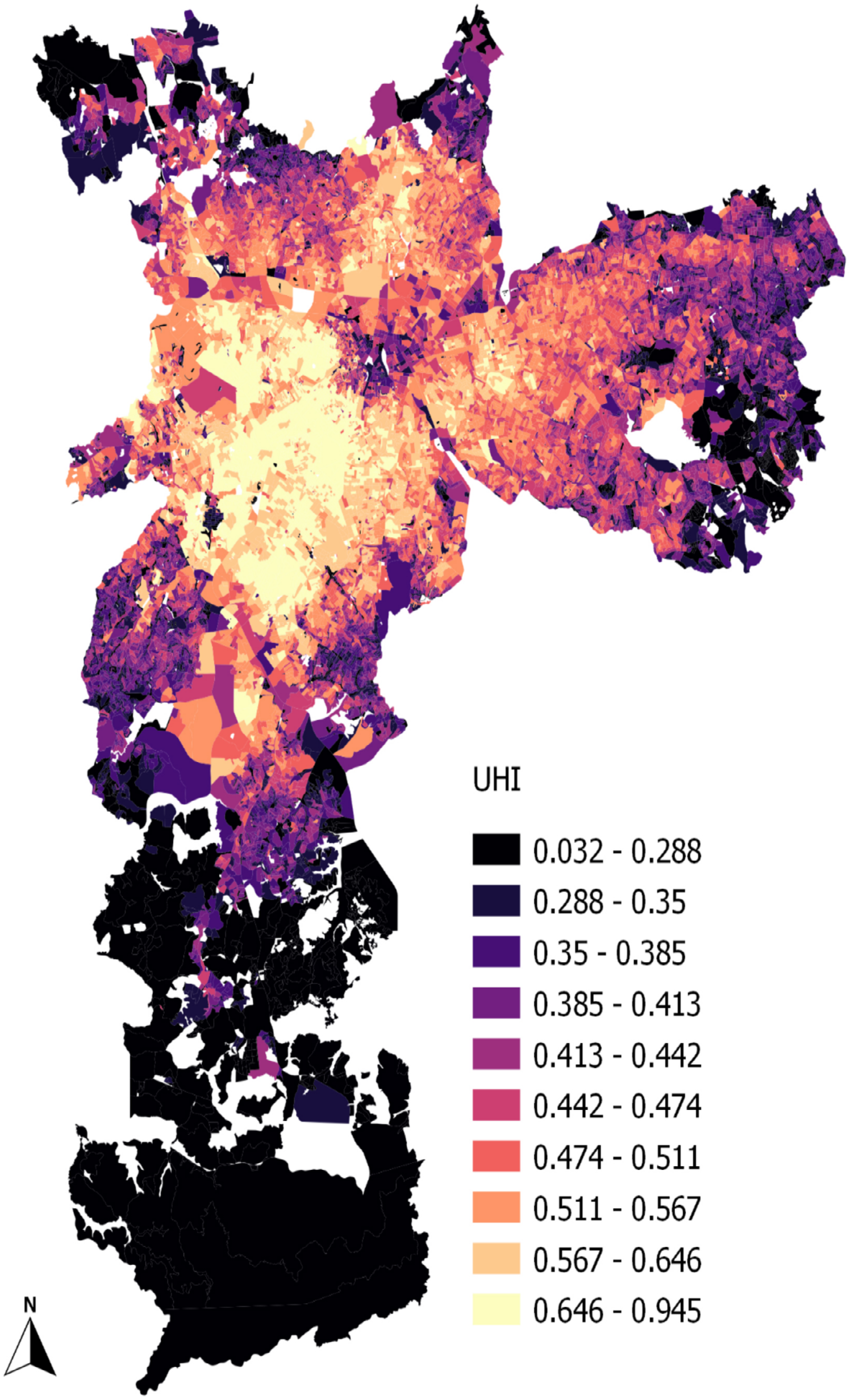

Figure 3. São Paulo urban health index.

The São Paulo UHI map presents a pattern similar to that of previous UHI studies[11,15,17]. Lighter hues (higher UHI values) can be seen in the center of the map, while towards the periphery, these hues tend to be darker (lower UHI values). This downtown-periphery dichotomy may be historically explained by the rapid process of urbanization of São Paulo when wealthy families clustered around the developed downtown area while low-class workers were pushed to the underdeveloped periphery of the capital[18].

According to the map, three regions have a higher level of health risk: east, northwest, and south. These areas share several similarities, including a high rate of population growth and migration, the absence of the state, and conflicts over territory. Furthermore, previous studies have identified them as areas of high social exclusion[17,19].

The south of the city, in particular, is the area with the worst UHI scores (<0.3) (Figure 3). Despite having the largest urban greenspace in São Paulo, this region presents a high risk of poor health due to its socioeconomic situation[20]. It is characterized by precarious infrastructure, and its population consists mainly of low-income families living in slums[7].

The UHI map of São Paulo offers a direct visual representation of disparities across its population. It shows that the marginalized populations are at higher risk of poor health, while central areas are at a lower risk. The results reveal not only the significant gap between the best-off and the worst-off units but also where they are located. The monitoring of health inequities proposed in this research is imperative to developing health policies that address the needs of the population.

The UHI method presented in this study is an important tool for raising political awareness; however, the dialogue with public health workers and decision-makers remains a challenge. For this reason, a simple and illustrative measure such as the UHI map would be of great value to favor this interaction.

This research provides a visual representation of health inequality in São Paulo City and may prove useful when identifying health needs that require public health attention. Moreover, this method provides the opportunity to evaluate changes and implement public health interventions when repeated periodically.

Next, the UHI method will be employed to measure and map health disparities in the state of São Paulo and Brazil. This method will allow policymakers at the state and federal levels to identify areas with high health risks.

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