Association of income level and ischemic heart disease: potential role of walkability

Rodrigo Julio Cerci (rjcerci@gmail.com)
Quanta Diagnostico
Miguel Morita Fernandes-Silva
Quanta Diagnostico
João Vicente Vitola
Quanta Diagnostico
Juliano Julio Cerci
Quanta Diagnostico
Carlos Cunha Pereira Neto
Quanta Diagnostico
Margaret Masukawa
Quanta Diagnostico
Ana Paula Weller Gracia
Pontifícia Universidade Católica do Paraná
Lara Luiza Silvello
Pontifícia Universidade Católica do Paraná
Pedro Prado
Quanta Diagnostico
Murilo Guedes
Pontifícia Universidade Católica do Paraná
Adriano Akira Ferreira Hino
Pontifícia Universidade Católica do Paraná
Cristina Pellegrino Baena
Pontifícia Universidade Católica do Paraná

Article

Keywords: Ischemic Heart Disease, Walkability, Income, Myocardial Perfusion Imaging.

Posted Date: May 6th, 2022

DOI: https://doi.org/10.21203/rs.3.rs-1608849/v1

Abstract

Background: Socioeconomic status has been linked to ischemic heart disease (IHD). High-income neighborhoods may expose individuals to a walking-promoting built environment for daily activities (walkability). Data from the association between income and IHD is lacking in middle-income countries (MIC). It is also uncertain whether walkability mediates this association.

Objectives: To investigate whether: income is associated with IHD in a MIC; and whether neighborhood walkability mediates the income-IHD association.

Methods: This cross-sectional study evaluated 44,589 patients referred for myocardial perfusion imaging (SPECT-MPI). Income and walkability were derived from participants' residential census tract. Walkability quantitative score combined four variables: street connectivity, residential density, commercial density, and mixed land use. IHD was defined by an abnormal myocardial perfusion during a SPECT-MPI study. We used adjusted mixed effects models to evaluate the association between income level and IHD; and performed a mediation analysis to measure the percentage of the income-IHD association mediated by walkability.

Results: From 26,415 participants, those living in the lowest income tertile census tract were more physically inactive (79.1 vs 75.8 vs 72.7%) when compared to higher income census tracts ($p<0.001$). Income was associated with IHD (OR 0.90 [95%CI 0.87 – 0.94] for each US$ 1,000.00 increase in income). Census tracts with higher income were associated with better walkability ($p <0.001$), however, walkability did not mediate the income-IHD association (percent mediated = -0.3%).

Conclusions: Income was independently associated with higher prevalence of IHD in a MIC. Although walkability was associated with census tract income, it did not mediate the income-IHD association.

Introduction

Ischemic heart disease (IHD) accounts for 7.4 million deaths per year worldwide with an estimated 2.1 billion dollars cost only for acute treatment of complications in Brazil[1, 2]. The diagnosis of IHD is well established, validated and available, using single-photon emission computed tomography myocardial perfusion imaging (SPECT-MPI) technique[3–5]. Several studies have determined the diagnostic and prognostic value of myocardial perfusion and left ventricular ejection fraction (LVEF) evaluated by SPECT, to predict adverse cardiovascular outcomes in several subgroups[6, 7].

Socioeconomic status (SES), has been associated with the development of cardiovascular disease[8, 9]. Several studies have shown that SES indirectly influences IHD by impacting on behavioral and metabolic cardiovascular risk factors, psychosocial factors, and environmental living conditions[10]. Social causation theory and conflict theory suggest health and behavioral problems result when resources and rewards are offered differently to different populations causing different levels of stress[11]. Association between income and IHD has been found in high income countries, but socioeconomic variables such as educational status, employment, health access and psychosocial factors are often tested in combination, where mediation analysis and the direct causality data of each of these factors is still lacking[10, 12]. For instance, income inequality has been linked to higher criminality, which has also been tied to reduced social cohesion. The lack of safety resulting from high crime and low cohesion may reduce outdoor physical activity, leading to increased blood pressure, body mass index, and other cardiovascular risk factors [13]. On the other hand, regular physical activity is associated with a better cardio metabolic risk profile and a lower risk of major cardiovascular events[14, 15] and a walking-promoting built environment for daily activities, also known as better walkability, have been positively associated with overall physical activity[16]. Some studies have shown that people living in neighborhoods with lower walkability have higher rates of cardio metabolic risk factors like diabetes, obesity, hypertension and sedentary life style and; a higher predicted 10-year cardiovascular disease risk [17–22]. These are all well-known risk factors for IHD, but it is still uncertain whether walkability can mediate an income-IHD association.

Finally, data from the income-IHD association is inconsistent in low and middle-income countries (MIC), which carries the highest burden of cardiovascular disease and have a diverse social, environmental and urban structure when compared to high-income countries [23–25]. The diverse magnitude and interpolation of these measurable socioeconomic variables in lower income countries may result in different correlations with IHD and such information can dramatically shift the already scarce resources allocation by the police makers, which need to focus on high impact policies to reduce IHD prevalence and mortality.

The objectives of this study were: (1) to investigate whether income level is associated with ischemic heart disease in a large urban center of a MIC; and (2) to test whether neighborhood walkability mediates the income-IHD association.

Methods

Population

We conducted a cross-sectional study that evaluated 26,415 consecutive patients above 18 years of age, covered private (n = 25,623; 96.5%) and public health insurance (n = 792; 3.5%), living in Curitiba, Brazil, from 44,589 patients who underwent a first clinically referred myocardial perfusion imaging with SPECT (SPECT-MPI), from February 2010 to August 2017, at a high-volume cardiovascular imaging center (Fig. 1). Curitiba is a large urban center in south Brazil, with 1,751,907 inhabitants, where 14.7% of the population received less than the minimum wage by the most updated Brazilian population census (2010)[26]. By the same census, the municipal Human Development Index was 0.823 and the Gini index, a ratio that represents income inequality and vary from 0 to 100%, was 56%[26]. The study was approved by the Pontifícia Universidade Católica do Paraná ethics committee (CAAE: 71331517.4.0000.00020) in accordance with international and local regulations. An exemption of specific consent was granted, since all individual data were collected and included in the institution registry when patients were submitted to the SPECT-MPI. All the individuals provide informed consent to use their data for scientific purposes before the exam.

Data collection for traditional cardiovascular risk factors

A trained nurse interviewed each participant before imaging acquisition. Data regarding age, gender, symptoms, past medical history, cardiovascular risk factors, and use of medications were collected. Hypertension, dyslipidemia, and diabetes mellitus were defined based on self-reported previous diagnosis or use of anti-hypertensive, lipid-lowering or antidiabetic medications. Positive family history of premature IHD was defined as first-degree relatives with early onset IHD (men $\leq$ 55 years, women $\leq$ 65 years). Physical activity was self-reported and considered as any at least 30 minutes aerobic exercise for health promotion, prevention or treatment of cardiovascular disease. Smoking status, prior history of known IHD (prior myocardial infarction, percutaneous revascularization, coronary bypass graft surgery or IHD confirmed by coronary angiography), height and weight were also self-reported.

Socio economic and walkability variables

Socio economic variables were collected from the most updated Brazilian population census (2010) and homicides data were received from the Department of Public Safety of the State of Paraná.[26] Each participant address was geocoded using specific online platform (Google Geocoding API Maps, Alphabet Inc, EUA), and individual variables were derived from participant's residential census tract, including: the average income in Brazilian currency (Real) per month, education level defined by literacy (illiterate or literate in any level); and criminality level stratified by the number of homicides per 100.000 inhabitants per year. The income was further converted into US dollars, by multiplying the average income in Brazilian Reais to the average exchange rate from the year 2010.

Walkability was measured for each census tract by a quantitative score combining street connectivity, residential density, commercial density and mixed land use, obtained through data layers, as previously described[16]. Raw values for each indicator were than normalized using z-scores. Finally, a walkability z-score was obtained by averaging each indicator z-score, and used as a continuous variable as described elsewhere.[27]

SPECT-MPI acquisition and analysis

The outcome variable was the presence of IHD at the participant level, defined by an abnormal myocardial perfusion during the SPECT-MPI study. All participants were submitted to stress and rest imaging acquisitions after intravenous injection of weight adjusted 20–25 mCi of ^{99m}Tc-sestamibi. Images started 30–60 minutes after injection at rest and 15–30 minutes after injection at peak stress. Conventional image protocol acquisition using standard energy windows for ^{99m}Tc in dual-head gamma cameras with a low-energy all-purpose collimator was performed. No attenuation correction was used.

Semi-quantitative visual interpretation of SPECT-MPI was performed by consensus of 2 experienced, board-certified observers using short-axis and vertical long-axis slices, divided into 17 standard segments for each patient using specific software (QPS, Cedars-Sinal, Los Angeles, California).[28] Each segment was scored based on the tracer uptake as: 0, normal; 1, mildly reduced; 2, moderately reduced; 3, severely reduced; and 4, absent tracer uptake in rest and stress images. A summed stress score (SSS) were obtained by adding the scores of the 17 segments of the stress images. Studies were classified as normal (SSS < 4) or abnormal (SSS ≥ 4).

Statistical Analysis

Participants were divided by income tertiles per census tract, only for variable comparisons between groups. We used a linear regression model with the income tertiles as outcome variable to compare continuous variables. For binary variables, the Mantel Haenzel test for linear tendencies between the tertiles was used. We drafted a directed acyclic graph (DAG) and used as a visual representation of causal assumptions (supplemental material) to select the variables for the models. We also used an inverse probability weighting (IPW) term in all models, accounting for the distance between the participant address and the cardiovascular imaging center. To account for the correlation between individuals living in the same census tract, we built multilevel (2 levels) models from mixed effects models to adjust for potential confounding variables to evaluate: (1) the association between income level (as a continuous variable) and IHD, and (2) performed a mediation analysis to measure the percentage of the income-IHD association mediated by walkability. In the first level the individual variables were included (age, gender and cardiovascular risk factors). In the second level, variables derived from the census tract were included (income, walkability and literacy). The software Stata version 15 (Stata Corp, College Station, Texas/EUA) was used for analysis and we consider a p value below 0.01 as statistically significant.

Results

Population characteristics

We collected data from 26,415 participants, living in 2168 out of the 2193 census tracts of Curitiba (Fig. 2). Most participants address were within 10 kilometers (km) from the imaging center (46.4% within 5 km, 39,0% between 5 and 10 km, 12,6% between 10 and 15 km and 2% more than 15 km). The clinical characteristics of the population are presented in Table 1. Those living in the lowest income tertile census tracts were younger (60.8 ± 12.3 vs 63.1 ± 12.6 vs 64.7 ± 12.2 years old; predominately women (52.1% vs 48.6% vs 46.6%); with higher body mass index (28.4 ± 5.2 vs 27.7 ± 4.7 vs 27.4 ± 4 kg/m^2); more physically inactive (79.1 vs 75.8 vs 72.7%); with a higher prevalence of prior myocardial infarction (12.0 vs 10.2 vs 8.9%); and had a higher prevalence of abnormal SPECT-MPI results (31.5 vs 30.4 vs 29.1%), when compared to the mid and the higher tertiles respectively, all with $p < 0.001$. The only traditional risk factors that was not more prevalent in those living in the lowest income tertile was dyslipidemia (52.6 vs 52.9 vs 53.7%, $p = 0.13$).

Table 1
Population characteristics and SPECT-MPI results by income.

Monthly income	1st Tertile (US$)	2nd Tertile (US$)	3rd Tertile (US$)	
	(192.5–843.6)	(844.1–1496.0)	(1496.4–4796.5)	
Socioeconomic variables by census track	n = 1299	n = 531	n = 338	p value
Walkability z-score, mean ± SD	-0.52 ± 1.51	0.64 ± 3.01	1.79 ± 2.75	$p < 0.001$
Mean proportion of literate, mean ± SD	0.96 ± 0.02	0.99 ± 0.01	0.99 ± 0.01	$p < 0.001$
Homicide rate per 100,000 inhab, n (IQR)	81.9 (0.0, 180.5)	0.0 (0.0, 89.8)	0.0 (0.0, 0.0)	$p < 0.001$
Traditional risk factors by patient	n = 8806	n = 8809	n = 8800	
Age, mean years ± SD	60.82 ± 12.36	63.08 ± 12.63	64.74 ± 12.26	$p < 0.001$
Female gender, n (%)	4586 (52.1%)	4283 (48.6%)	4103 (46.6%)	$p < 0.001$
BMI, mean kg/m^2 ± SD	28.38 ± 5.22	27.69 ± 4.74	27.43 ± 4.51	$p < 0.001$
Hypertension, n (%)	5752 (65.3%)	5463 (62.0%)	5241 (59.6%)	$p < 0.001$
Diabetes, n (%)	2362 (26.8%)	2070 (23.5%)	2003 (22.8%)	$p < 0.001$
Dyslipidemia, n (%)	4629 (52.6%)	4660 (52.9%)	4724 (53.7%)	$p = 0.13$
Family hx of premature IHD, n (%)	1610 (18.3%)	1572 (17.8%)	1459 (16.6%)	$p = 0.003$
Smoking, n (%)	894 (10.2%)	797 (9.0%)	754 (8.6%)	$p < 0.001$
Physical inactivity, n (%)	6962 (79.1%)	6675 (75.8%)	6393 (72.7%)	$p < 0.001$
Prior history of known IHD				
Prior percutaneous revascularization, n (%)	1302 (14.8%)	1297 (14.7%)	1256 (14.3%)	$p = 0.34$
Prior CABG, n (%)	600 (6.8%)	519 (5.9%)	529 (6.0%)	$p = 0.028$

Monthly income	1st Tertile (US$)	2nd Tertile (US$)	3rd Tertile (US$)	
Previous MI, n (%)	1053 (12.0%)	900 (10.2%)	784 (8.9%)	p < 0.001
Symptoms				
Atypical chest pain, n (%)	2561 (29.2%)	1996 (22.8%)	1686 (19.3%)	p < 0.001
Typical chest pain, n (%)	658 (7.5%)	513 (5.9%)	395 (4.5%)	p < 0.001
SPECT-MPI				
Abnormal myocardial perfusion, n (%)	2771 (31.5%)	2682 (30.4%)	2564 (29.1%)	p < 0.001
SD, standard deviation; IQR, interquartile range; BMI, body mass index; Hx, family history; IHD, ischemic heart disease; CABG, coronary artery bypass graft; MI, myocardial infarction, SPECT-MPI, Single-photon emission computed tomography myocardial perfusion imaging.				

Association of income level with ischemic heart disease

After adjusting for potential confounders, income level was inversely associated with IHD (Fig. 3A), with an OR 0.90 (95% CI 0.87–0.94) for each US$ 1,000.00 increase in income. On the other hand, walkability was not associated with IHD (OR 1.00, 95%CI 0.99–1.02) (Fig. 3B). Other traditional risk factors like, diabetes, smoking, family history of premature IHD and physical inactivity were also associated with IHD, with diabetes having the strongest association with an OR of 1.57 (95% CI 1.44– 1.72) (Table 2).

Table 2
Multilevel mixed effects model having IHD as outcome.

Variable	OR	95% CI	P value
Income per US$1.000,00	0.90	0.87–0.94	p < 0.001
Walkability; z-score	1.00	0.99–1.02	p = 0.72
Age; years	1.04	1.035–1.042	p < 0.001
Female gender	1.02	0.94–1.10	p = 0.68
BMI; kg/m2	1.02	1.01–1.03	p < 0.001
Hypertension	1.09	1.00–1.19	p = 0,05
Diabetes	1.57	1.44–1.72	p < 0.001
Dyslipidemia	0.96	0.89–1.04	p = 0,35
Family hx of premature IHD	1.01	0.91–1.12	p = 0.84
Smoking	1.32	1.16–1.51	p < 0.001
Physical inactivity	1.41	1.28–1.55	p < 0.001
Previous MI	3.58	3.09–4.14	p < 0.001
Illiteracy by census track	4.97	0.81–30.4	p = 0.08
BMI, body mass index; Hx, family history; IHD, ischemic heart disease; MI, myocardial infarction			

Mediation effect of walkability on the association of income level and ischemic heart disease

Census tracts with lower income levels were associated with lower walkability z-scores (-0.52 [95%CI: -0.60;0.44] vs 0.64 [95%CI: 0.38;0.89] vs 1.79 [95%CI: 1.49;2.08]) from the lower to the higher income tertile respectively (βeta: 0.115 ± 0.002, $p < 0.001$ – Fig. 3C), but walkability did not significantly mediate the association between income level and IHD (percent mediated = -0.3%). We also tested the influence of criminality on this mediation and found that walkability mediated 0% (95%CI 0%-28%) of the income-IHD association in census tracts with no homicides per 100,000 inhabitants; and mediated 3% (95%CI 0% – 18%) in census tracts with at least one homicide per 100,000 inhabitants.

Discussion

The key findings of this investigation can be summarized as follows: (1) income level is independently and inversely associated with IHD in a large urban center in a MIC population; and (2) although neighborhoods with lower income levels were associated with lower walkability scores, walkability did not explain the association between income level and IHD.

Association of income level and ischemic heart disease

The odds of an abnormal SPECT-MPI decreased 10% for each US$ 1,000.00 increase in participant census track income. Income-IHD association has been found in high income countries, but data has been inconsistent in middle income countries (MIC) [10, 12, 23, 24] . Data from neighbors' middle income countries Bosnia-Herzegovina and Serbia shown opposite results [29, 30] . Jankovic et al did not find any association between income and global cardiovascular health in Bosnia-Herzegovina while Vukovic et al found direct association of income and traditional cardiovascular risk factors in Serbia, where the richest had the higher risk of hypertension and dyslipidemia (OR 1.32 [95%CI: 1.08–1.62] and OR 2.71 [95%CI: 2.05–3.59], respectively). A systematic review of 53 studies concluded that IHD mortality is higher among the richest in India, a low-middle income country [31] . Our data builds on the knowledge that income and IHD association may be present in MIC, independently of traditional risk factors.

The reason why we cannot extrapolate high income countries associations to low and middle-income countries is the diverse social, environmental and urban structure between countries and regions that goes beyond income level alone. One example of this diversity is the distribution of obesity within the population of different countries[32]. Obesity is a well-known cardiovascular risk factor, which became epidemic between the poor in high-income countries like the United State of America, but is still a disease of the rich in low-income countries where only the higher income population have access to the obesity prone western diet[32].

Brazil has been undergoing an epidemiological transition over the past 30 years with an overall decline in communicable diseases and increasing non-communicable disease burden, where IHD became the leading cause of death[33]. Nevertheless, even within Brazil, different states have faced different timing on this transition. While the higher income southern and southeastern states started the transition earlier, the lower income states of the north and northeast are still on the move and facing an increase in IHD mortality[33, 34]. Curitiba is in south of Brazil, where the epidemiological transition is more advanced, which may explain an income-IHD association more similar to the one found in developed countries.

Mediation effect of walkability on the association of income level and ischemic heart disease

Increased individual stress is the most widely described explanation for health disparity by socioeconomic status. Lower-income individuals have more stress, including insecurity in housing, income, food access and safety, while also having fewer resources to deal with these challenges, which leads to increased risky behavior such as smoking, alcohol abuse and physical inactivity. Such behavior translates into higher prevalence of traditional risk factors and cardiovascular disease[11].

Several studies also found association between walkability and cardiovascular risk factors, notably in developed and high-income countries, where physical inactivity was pointed out as the main mediator of such association[17–20, 35–38]. Since population leaving in low walkability census tracts in Curitiba has been shown to be less physically active[16, 21] and we demonstrated in this study that low walkability census tracts are associated with a lower income population in the same city, we found equipoise to test if walkability could mediate some of the income-IHD association. For the best of our knowledge, this is the first study to test the possible mediation of walkability on the income level-IHD association, which usually represents an advanced pathological endpoint of patient's exposure to a combination of many of these traditional, socioeconomic and environmental risk factors over s long period of time[39]. We did not find a significant mediation of walkability on the income level-IHD association.

Limitations

The main limitations of this study are related to the cross-sectional design and the inherent bias of such analysis, that may be mitigated by our large sample size and by the use of a IPW term to account for the distance between the participants address and the cardiovascular imaging center (selection bias). We calculated the exposition variable income based on the address of the participants at the time of the SPECT-MPI study, not considering for how long they have been exposed to such income. Finally, there may be some referral bias since all patients were clinically referred for the SPECT-MPI and not randomly sampled from each census tract of the city of Curitiba.

Conclusions

In this large registry in a large MIC urban center, living in a low-income census tract was independently associated with higher prevalence of IHD. Although walkability was directly associated with census tract income, it did not mediate the association between income level and IHD.

Abbreviations

DAG
Directed acyclic graph
IHD
Ischemic heart disease
IPW
inverse probability weighting
MIC
middle-income country
SES
Socioeconomic status
SPECT-MPI
Single-photon emission computed tomography myocardial perfusion imaging
SSS
Summed stress score

Declarations

Disclosures

RJC received scholarship from CAPES (Coordenação de Aperfeiçoamento de Pessoal de Nível Superior), an Education Ministry foundation, as part of a PhD thesis. The other authors declare they have no financial or conflict of interest to disclose.

Clinical Perspectives

Competency in Medical Knowledge: There is a strong association of income level and ischemic heart disease that cannot be explained by neighborhood walkability in a large middle income country urban area.

Translational Outlook: Policies to raise the population overall income can potentially decrease the prevalence of ischemic heart disease.

Data availability

The datasets analysed during the current study are available from the corresponding author on reasonable request.

Author's contributions

Rodrigo Julio Cerci: study design, literature search, data collection, data analysis, data interpretation, and writing.

Miguel Morita Fernandes-Silva: study design, literature search, data collection, data analysis, data interpretation, and reviewing.

João V. Vitola: data collection, reviewing.

Juliano Julio Cerci: data collection, reviewing.

Carlos Cunha Pereira Neto: data collection, reviewing.

Margaret Masukawa: data collection, reviewing.

Ana Paula Weller Gracia: data collection, reviewing.

Lara Luiza Silvello: data collection, reviewing.

Pedro Prado: data collection, reviewing.

Murilo Guedes: data interpretation and reviewing.

Adriano Akira Ferreira Hino: study design, data collection, data interpretation, data analysis, and reviewing

Cristina Pellegrino Baena: study design, data interpretation, data analysis, and reviewing

References

1. Teich V, Piha T, Fahham L, et al. Acute Coronary Syndrome Treatment Costs from the Perspective of the Supplementary Health System. Arq Bras Cardiol. Oct 2015;105(4):339–44. doi:10.5935/abc.20150129
2. WHO. Disease burden and mortality estimates. Updated 29 September 2020. Accessed 28 September 2020, 2020. https://www.who.int/healthinfo/global_burden_disease/estimates/en/
3. Cerqueira MD, Harp GD, Ritchie JL. Evaluation of myocardial perfusion and function by single photon emission computed tomography. Semin Nucl Med. Jul 1987;17(3):200–13. doi:10.1016/s0001-2998(87)80034-x
4. Germano G, Kiat H, Kavanagh PB, et al. Automatic quantification of ejection fraction from gated myocardial perfusion SPECT. J Nucl Med. Nov 1995;36(11):2138–47.
5. Einstein AJ, Pascual TN, Mercuri M, et al. Current worldwide nuclear cardiology practices and radiation exposure: results from the 65 country IAEA Nuclear Cardiology Protocols Cross-Sectional Study (INCAPS). Eur Heart J. Jul 7 2015;36(26):1689–96. doi:10.1093/eurheartj/ehv117
6. Cerci MSJ, Cerci JJ, Cerci RJ, et al. Myocardial perfusion imaging is a strong predictor of death in women. JACC: Cardiovascular Imaging. 2011;4(8):880–888.
7. Shaw L, Chaitman BR, Hilton TC, et al. Prognostic value of dipyridamole thallium-201 imaging in elderly patients. J Am Coll Cardiol. Jun 1992;19(7):1390–8. doi:10.1016/0735-1097(92)90592-b
8. Schultz WM, Kelli HM, Lisko JC, et al. Socioeconomic Status and Cardiovascular Outcomes: Challenges and Interventions. Circulation. 2018;137(20):2166–2178.
9. Nieuwenhuijsen MJ. Influence of urban and transport planning and the city environment on cardiovascular disease. Nature Reviews Cardiology. 2018:1.
10. Khaing W, Vallibhakara SA, Attia J, McEvoy M, Thakkinstian A. Effects of education and income on cardiovascular outcomes: A systematic review and meta-analysis. Eur J Prev Cardiol. Jul 2017;24(10):1032–1042. doi:10.1177/2047487317705916
11. Lemstra M, Rogers M, Moraros J. Income and heart disease: Neglected risk factor. Canadian family physician Medecin de famille canadien. 2015;61(8):698–704.
12. Havranek EP, Mujahid MS, Barr DA, et al. Social Determinants of Risk and Outcomes for Cardiovascular Disease: A Scientific Statement From the American Heart Association. Circulation. Sep 2015;132(9):873–98. doi:10.1161/CIR.0000000000000228
13. Diez Roux AV. Residential environments and cardiovascular risk. J Urban Health. Dec 2003;80(4):569–89. doi:10.1093/jurban/jtg065

14. Lear SA, Hu W, Rangarajan S, et al. The effect of physical activity on mortality and cardiovascular disease in 130 000 people from 17 high-income, middle-income, and low-income countries: the PURE study. Lancet. Dec 16 2017;390(10113):2643–2654. doi:10.1016/s0140-6736(17)31634-3
15. Wahid A, Manek N, Nichols M, et al. Quantifying the Association Between Physical Activity and Cardiovascular Disease and Diabetes: A Systematic Review and Meta-Analysis. Journal of the American Heart Association. 2016;5(9):e002495. doi:10.1161/JAHA.115.002495
16. Reis RS, Hino AAF, Rech CR, Kerr J, Hallal PC. Walkability and physical activity: findings from Curitiba, Brazil. American journal of preventive medicine. 2013;45(3):269–275.
17. Muller-Riemenschneider F, Pereira G, Villanueva K, et al. Neighborhood walkability and cardiometabolic risk factors in Australian adults: an observational study. BMC Public Health. Aug 15 2013;13:755. doi:10.1186/1471-2458-13-755
18. Sarkar C, Webster C, Gallacher J. Neighbourhood walkability and incidence of hypertension: Findings from the study of 429,334 UK Biobank participants. International journal of hygiene and environmental health. 2018;
19. den Braver NR, Lakerveld J, Rutters F, Schoonmade LJ, Brug J, Beulens JWJ. Built environmental characteristics and diabetes: a systematic review and meta-analysis. BMC Med. Jan 31 2018;16(1):12. doi:10.1186/s12916-017-0997-z
20. Méline J, Chaix B, Pannier B, Ogedegbe G, Trasande L, Duncan DT. Neighborhood walk score and selected Cardiometabolic factors in the French RECORD cohort study. BMC public health. 2017;17(1):960.
21. Hino AA, Reis RS, Sarmiento OL, Parra DC, Brownson RC. Built environment and physical activity for transportation in adults from Curitiba, Brazil. Journal of Urban Health. 2014;91(3):446–462.
22. Howell NA, Tu JV, Moineddin R, Chu A, Booth GL. Association Between Neighborhood Walkability and Predicted 10-Year Cardiovascular Disease Risk: The CANHEART (Cardiovascular Health in Ambulatory Care Research Team) Cohort. J Am Heart Assoc. 11 2019;8(21):e013146. doi:10.1161/JAHA.119.013146
23. Roth GA, Huffman MD, Moran AE, et al. Global and regional patterns in cardiovascular mortality from 1990 to 2013. Circulation. Oct 27 2015;132(17):1667–78. doi:10.1161/CIRCULATIONAHA.114.008720
24. Rosengren A, Smyth A, Rangarajan S, et al. Socioeconomic status and risk of cardiovascular disease in 20 low-income, middle-income, and high-income countries: the Prospective Urban Rural Epidemiologic (PURE) study. Lancet Glob Health. 06 2019;7(6):e748-e760. doi:10.1016/S2214-109X(19)30045-2
25. Adjaye-Gbewonyo K, Kawachi I, Subramanian SV, Avendano M. Income inequality and cardiovascular disease risk factors in a highly unequal country: a fixed-effects analysis from South Africa. Int J Equity Health. 03 2018;17(1):31. doi:10.1186/s12939-018-0741-0
26. IBGE. Census 2010. IBGE. Accessed July 2019. https://censo2010.ibge.gov.br/

27. Leslie E, Coffee N, Frank L, Owen N, Bauman A, Hugo G. Walkability of local communities: using geographic information systems to objectively assess relevant environmental attributes. Health & place. 2007;13(1):111–122.
28. Cerqueira MD, Weissman NJ, Dilsizian V, et al. Standardized myocardial segmentation and nomenclature for tomographic imaging of the heart: a statement for healthcare professionals from the Cardiac Imaging Committee of the Council on Clinical Cardiology of the American Heart Association. Circulation. 2002;105(4):539–542.
29. Jankovic J, Eric M, Stojisavljevic D, Marinkovic J, Jankovic S. Socio-Economic Differences in Cardiovascular Health: Findings from a Cross-Sectional Study in a Middle-Income Country. PLoS One. 2015;10(10):e0141731. doi:10.1371/journal.pone.0141731
30. Vukovic D, Bjegovic V, Vukovic G. Prevalence of chronic diseases according to socioeconomic status measured by wealth index: health survey in Serbia. Croat Med J. Dec 2008;49(6):832–41. doi:10.3325/cmj.2008.49.832
31. Subramanian SV, Corsi DJ, Subramanyam MA, Smith GD. Jumping the gun: the problematic discourse on socioeconomic status and cardiovascular health in India. Int J Epidemiol. Oct 2013;42(5):1410–26. doi:10.1093/ije/dyt017
32. Dinsa GD, Goryakin Y, Fumagalli E, Suhrcke M. Obesity and socioeconomic status in developing countries: a systematic review. Obes Rev. Nov 2012;13(11):1067–79. doi:10.1111/j.1467-789X.2012.01017.x
33. Collaborators GB. Burden of disease in Brazil, 1990–2016: a systematic subnational analysis for the Global Burden of Disease Study 2016. *Lancet*. Sep 1 2018;392(10149):760–775. doi:10.1016/s0140-6736(18)31221-2
34. Baena CP, Chowdhury R, Schio NA, et al. Ischaemic heart disease deaths in Brazil: current trends, regional disparities and future projections. Heart. Sep 2013;99(18):1359–64. doi:10.1136/heartjnl-2013-303617
35. Coffee NT, Howard N, Paquet C, Hugo G, Daniel M. Is walkability associated with a lower cardiometabolic risk? Health & place. 2013;21:163–169.
36. Mason KE, Pearce N, Cummins S. Associations between fast food and physical activity environments and adiposity in mid-life: cross-sectional, observational evidence from UK Biobank. The Lancet Public Health. 2018;3(1):e24-e33. doi:10.1016/s2468-2667(17)30212-8
37. Paquet C, Coffee NT, Haren MT, et al. Food environment, walkability, and public open spaces are associated with incident development of cardio-metabolic risk factors in a biomedical cohort. Health & place. 2014;28:173–176.
38. Sallis JF, Cerin E, Conway TL, et al. Physical activity in relation to urban environments in 14 cities worldwide: a cross-sectional study. Lancet. May 28 2016;387(10034):2207–17. doi:10.1016/S0140-6736(15)01284-2
39. Bhatnagar A. Environmental Determinants of Cardiovascular Disease. Circ Res. Jul 7 2017;121(2):162–180. doi:10.1161/CIRCRESAHA.117.306458

Figures

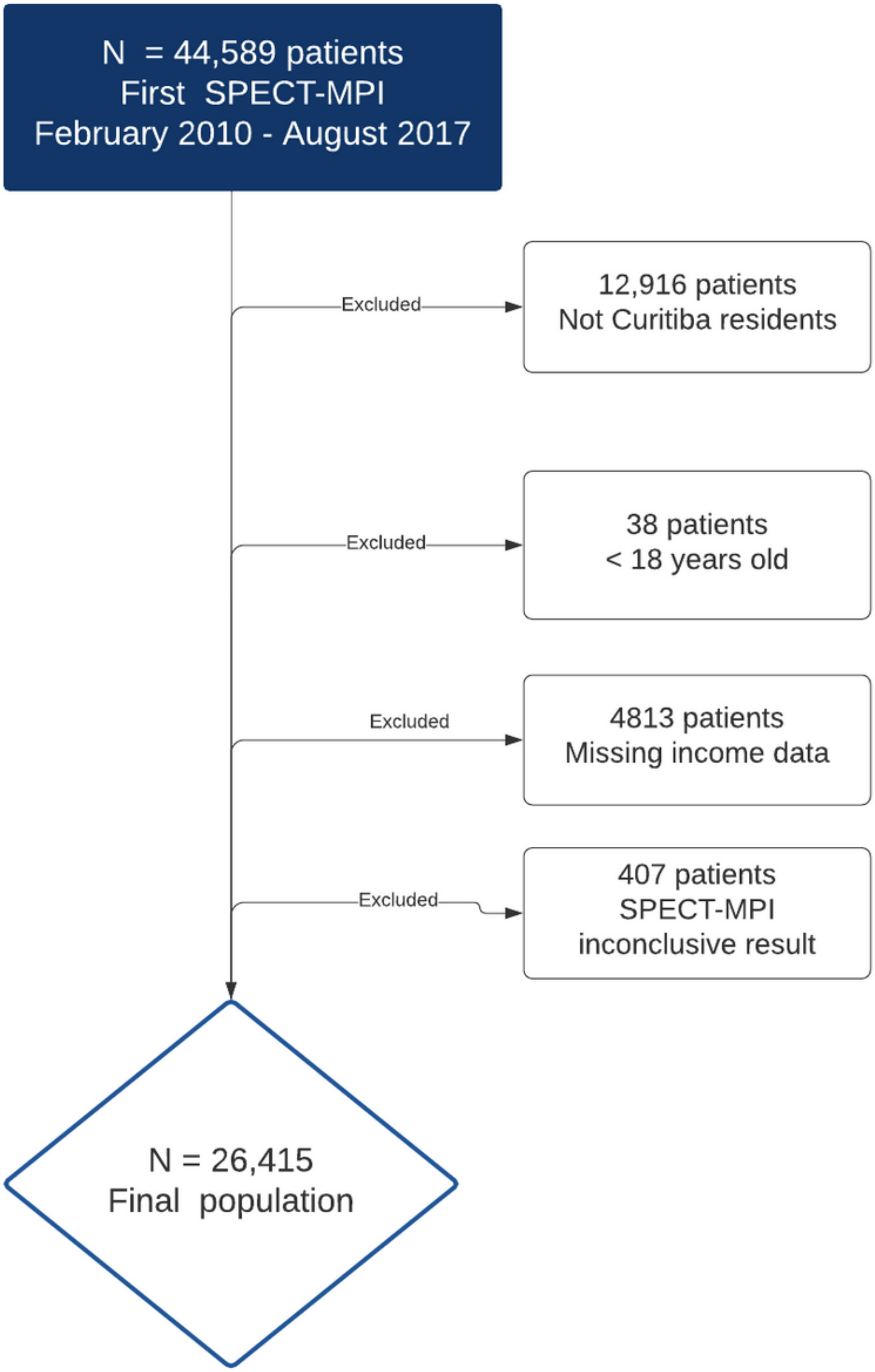

Figure 1

Exclusion criteria flow chart.

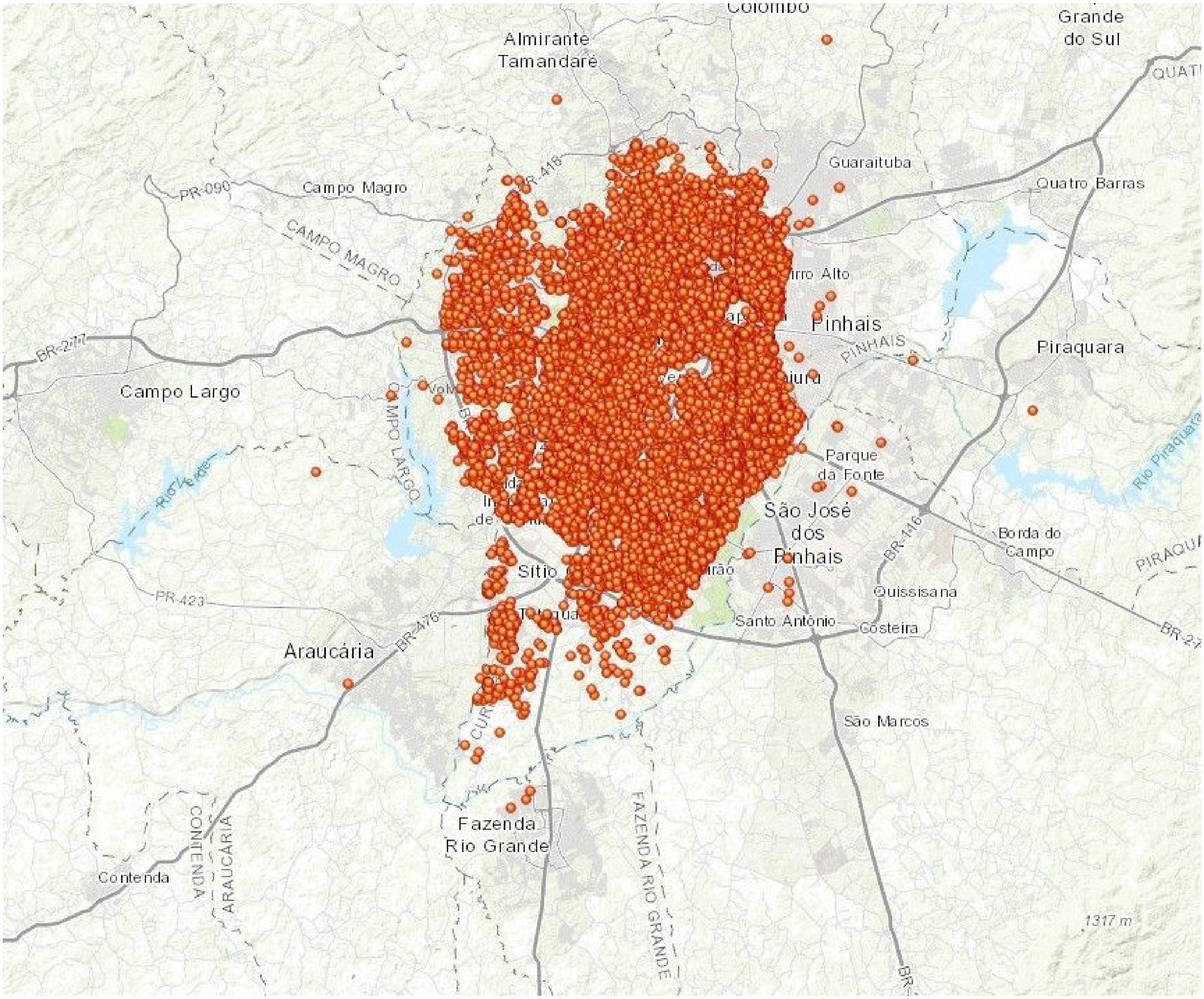

Figure 2

Geocoded addresses of the 26,415 participants in Curitiba.

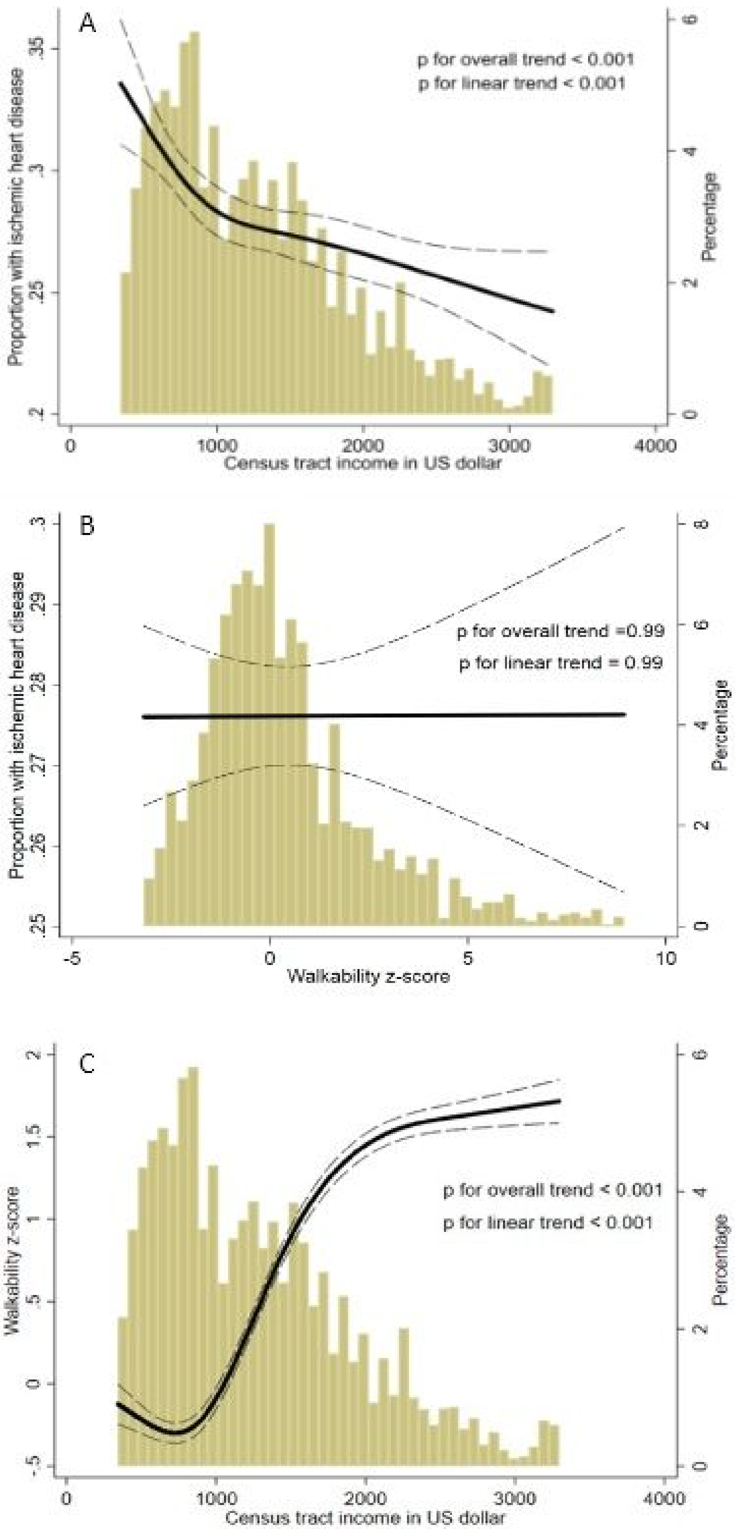

Figure 3

(Central Illustration): Association of income level (Panel A), walkability z-score (Panel B) and ischemic heart disease adjusted for traditional risk factors and socioeconomic variables. Panel C: Association of income level and walkability z-score.

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- STROBEchecklistcrosssectionalScientificReports.docx
- SupplementalmaterialDAG.docx