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## Built environment correlates of overweight and obesity among adults in Chennai, India

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### ABSTRACT

Overweight and obesity are steadily rising in South Asia, the world's most populous region. India, a low- and middle-income country in South Asia is experiencing an obesity epidemic. Built environment features may profoundly influence physical activity and counter the risk from overweight and obesity. This cross-sectional study investigated built environment correlates of overweight and obesity among adults (N = 370, 47.2% female, mean age = 37.9 years) in Chennai, India. Participants from low-socioeconomic status households were more likely to be overweight/obese (odds ratio [OR] = 1.8, 95% confidence interval [CI] = 1.1–2.9) than participants from high-socioeconomic status households. Driving to work predicted a three-fold increase in overweight or obesity compared to active commuting (OR = 2.9, 95%CI = 1.3–6.4). Household car ownership was linked with an increased likelihood of overweight or obesity (OR = 1.5, 95%CI = 0.7–3.2). Low walkability neighbourhoods significantly predicted an increase in odds of overweight or obesity (OR = 1.8, 95%CI = 1.1–2.8). By 2030, Indian cities are projected to add 250 million people accompanied by a 9.9% annual motor vehicle growth rate. As car ownership increases across Southern Asia, there is an urgent need to develop interventions to promote physical activity.

### ARTICLE HISTORY

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Obesity; overweight; physical activity; active commuting; built environment; India

### Introduction

The increasing prevalence of overweight and obesity continues to be a major public health concern globally (Jaacks *et al.* 2019). According to recent global estimates, more than 1.9 billion adults aged 18 years and older were overweight in 2016, and of these, over 650 million adults were obese (Guthold *et al.* 2018). Obesity and overweight are risk factors for a range of health problems, including cardiovascular disease, stroke, type-2 diabetes, hypertension and some cancers (Guh *et al.* 2009, Beaglehole *et al.* 2011, Lauby-Secretan *et al.* 2016). South Asia, the world's most densely populated geographical region that is home to one-quarter of the world's population (nearly 1.9 billion), is facing an obesity crisis with recent estimates suggesting that two out of every five adults in the region are either overweight or obese (Helble and Francisco 2017). Once considered a high-income country problem, overweight and obesity are now on the rise in low- and middle-income countries, particularly in urban settings, even as they continue to struggle with a burden of infectious disease (Prentice 2006, Swinburn *et al.* 2011, Siddiqui *et al.* 2015).

India, a low- and middle-income country located in South Asia and the second-most populous country in the world, is witnessing an obesity epidemic where the

prevalence of overweight and obesity along with other non-communicable diseases has been rising steadily (Meshram *et al.* 2016). The Chennai Urban-Rural Epidemiology Study determined that the age-standardized prevalence of generalized obesity in an adult population was 45.9% (95% CI: 43.9–47.9) (Deepa *et al.* 2003). In another study, the prevalence of obesity among an urban adult population was 55.5% (95% CI: 47.2–63.4), indicating a high burden of disease (Rautela *et al.* 2018). A comparative study across three Indian states found the prevalence of generalized obesity ranged from 11.8% to 33.6% (Pradeepa *et al.* 2015). A comparison of two major studies conducted by the National Family Health Survey in 1998–1999 and in 2005–2006 highlighted that the prevalence of obesity among Indian women elevated from 10.6% to 12.6% (Garg *et al.* 2010).

The pace at which obesity prevalence has grown at the population level across the globe points to social and environmental causes. This sum of influences that the surroundings, opportunities, or prevailing conditions of life have on promoting weight gain and obesity in individuals or populations characterises certain environments as more 'obesogenic' than others. Obesogenic environments

are characterised by increasing urbanization, use of mechanized transport, increased television viewing, adoption of less physically active lifestyles and rise in sedentary (sitting) time (Mackenbach *et al.* 2014). Calls to address the global epidemic of obesity by the World Health Organization have recommended increasing physical activity as a key strategy, highlighting the role of the built environment to support physical activity as a central focus area (World Health Organization 2019). Neighbourhoods that are activity-friendly depend upon an appropriate integration of land-use and transportation infrastructure, including higher residential densities and street connectivity (Sallis *et al.* 2020). The availability of pedestrian, bicycling and transit infrastructure such as sidewalks, crosswalks, bicycle lanes and access to public transport services (e.g. bus rapid transit, light rail) has been linked with increased levels of transport-related physical activity (Kerr *et al.* 2016b).

A number of studies from Australasia, Europe, North America and South America have documented positive associations between walkable, mixed-use, transit-accessible neighbourhoods and individuals' levels of physical activity and healthy weight status compared with those living in automobile-dependent neighbourhoods (Sallis *et al.* 2020). Findings from existing studies do not lend themselves easily to generalization in other parts of the world, particularly the South Asia region that is home to over 24% of the world's population and at high risk of developing obesity (Milton *et al.* 2014, Elshahat *et al.* 2020). Although these studies show a consistent correlation between neighbourhood built environment and the prevalence of obesity in developed countries, these relationships have not been examined in India. The objective of the current study was to examine the built environment correlates of overweight and obesity among adults in the city of Chennai, India.

## Methods

### Study area

This study recruited a diverse sample of participants ( $N = 370$ ) from Chennai city (164.5 sq. miles, population = 7.09 million), capital of the state of Tamil Nadu in southern India. Tamil Nadu is the most urbanized state in India with 48.4% of the population living in urban areas (Ministry of Urban Development [MOUD] 2013) and has the highest number of diabetic cases, a majority of them reported in Chennai (Gupta *et al.* 2010). The city has also seen a 24-fold increase in motorized vehicles in the last 10 years with private automobiles now constituting 55% of daily all-person trips (Government of Tamil Nadu 2014). For administrative purposes, the Chennai

metropolitan area is divided into 155 smaller subdivisions called wards, which were the primary unit of sampling in this study. Wards the smallest geographic areas for which the Census Bureau of India publishes demographic information (compare to US census tracts) (Office of the Registrar General & Census Commissioner 2011). The Institutional Review Board of (removed for peer review) approved all study procedures.

### Sampling and recruitment

Study protocols were based on the recommendations of the International Physical activity and the Environment Network (IPEN; [www.ipenproject.org](http://www.ipenproject.org)) (Adlakha *et al.* 2016a). Participants were recruited through purposive sampling from wards stratified by walkability and socioeconomic status, to maximize variance and enhance the representativeness of the sample as low-income populations tend to be under-represented in studies of this nature (Turrell 2000, Cerin *et al.* 2009).

Inclusion and exclusion criteria were based on IPEN protocol and studies conducted in Africa, Brazil and China (Saelens *et al.* 2003, Cerin *et al.* 2013, Oyeyemi *et al.* 2013, 2016b, Salvo *et al.* 2014). Eligibility criteria for participants included: (i) current residents of Chennai; (ii) residents for at least 6 months; (iii) 18–65 years of age; (iv) able to answer questions in English or Tamil; (v) not having any disability that prevented independent walking; and (vi) no visible signs of cognitive impairment. One individual per household was recruited to ensure the independence of observations. The sample size was determined using a moderate-to-large effect size (effect size [ $d$ ] = 0.75), which is greater than what has been used previously IPEN studies in low- and middle-income country contexts such as Africa, Brazil and China (Saelens *et al.* 2003, Cerin *et al.* 2013, Oyeyemi *et al.* 2013, 2016b, Salvo *et al.* 2014).

## Measures

### Neighbourhood walkability

The Neighbourhood Environment Walkability Scale – India (NEWS-India) was used to assess built environment features of participants' home neighbourhoods. NEWS-India consists of 91 items grouped into the following subscales: (a) residential density, (b) land-use mix-diversity, (c) land-use mix-access, (d) street connectivity, (e) infrastructure for walking/bicycling, (f) aesthetics, (g) traffic safety and (h) safety from crime. Four-point Likert-type scale responses for all items ranging from 1 (strongly agree) to 4 (strongly disagree) were combined as 'agree' (strongly agree, agree) and 'disagree' (disagree, strongly disagree).

NEWS-India items were positively scored to ensure that a higher score represented an activity-supportive neighbourhood (Kerr 2013). Test–retest reliability of NEWS-India has been previously established, with intra-class correlation coefficients higher than 0.75, indicating excellent reliability (Adlakha *et al.* 2016a).

### Physical activity

Two modules of the International Physical Activity Questionnaire-Long Form (IPAQ-LF) were used to measure participants' leisure and travel physical activity (IPAQ 2002). IPAQ-LF is a self-report measure that captures the frequency and duration of walking, moderate-intensity and vigorous-intensity physical activity. It has been tested internationally with reliability (Spearman's rho ~0.8) and criterion validity (median rho ~0.3) comparable to other self-reported validation studies (Craig *et al.* 2003). Following World Health Organization recommendations, adults aged 18–64 years should engage in 150 minutes of moderate-intensity aerobic activity in a week to incur health benefits. In the context of daily, family and community activities, this can include leisure time activity (e.g. walking, dancing, gardening, hiking, swimming) or transportation (e.g. walking, bicycling) (World Health Organization 2019).

### Weight status (BMI)

Self-reported height and weight data were elicited from participants. Body mass index (BMI) was calculated as body weight divided by the square of height ( $\text{kg}/\text{m}^2$ ). The World Health Organization principal cutoff points for BMI were used to create the categories: underweight ( $<18.5 \text{ kg}/\text{m}^2$ ), normal weight ( $18.5\text{--}24.99 \text{ kg}/\text{m}^2$ ), overweight ( $25\text{--}24.99 \text{ kg}/\text{m}^2$ ) and obese ( $\geq 30 \text{ kg}/\text{m}^2$ ) (World Health Organization 2000).

### Demographic variables

Self-reported data on participants' age, gender, marital status, educational level, employment status and household socioeconomic status were recorded using validated scales (Bairwa *et al.* 2013). Household socioeconomic status was measured using a validated composite scale developed for India. This scale measures three variables, namely, education, occupation of the head of the household and income of the family (Gururaj 2014).

### Data analysis

Multiple logistic regression models were used to examine the factors associated with overweight or

obesity. Models were adjusted for age, gender, household socioeconomic status and motor vehicle ownership to control for the confounding effects of these variables as shown in similar studies conducted in low- and middle-income countries (Kerr *et al.* 2016a). The analysis was conducted using the Statistical Package for the Social Sciences (SPSS) v.25 (IBM Corp 2012).

## Results

Descriptive characteristics of the sample population are presented in Table 1. The mean age of the sample was 37.9 years. The majority of participants were women (54.2%), married (61.2%), employed (62.5%), with a graduate or professional degree (49.7%). Nearly half (48.2%) of the participants reported earning less than 600 US Dollars (approximately 36,017 Indian rupees) per month.

Anthropometric characteristics of participants by gender and income are presented in Table 2. Compared to high-socioeconomic status households, a higher number of participants from low-socioeconomic status households were overweight ( $n = 54$ , 25.4%) and obese ( $n = 31$ , 14.6%). Women were more likely to be obese ( $n = 31$ , 15.6%) than men.

Table 3 shows BMI, moderate-to-vigorous physical activity and sedentary levels across walkability

**Table 1.** Characteristics of the study population.

Descriptive Characteristics	Statistic
Age (in years), mean (SD)	37.9 (15.3)
Gender, n (%)	
Female	199 (53.8)
Male	166 (44.9)
Missing	5 (1.4)
Marital Status, n (%)	
Married	226 (61.1)
Not married	143 (38.6)
Missing	1 (0.3)
Educational Level, n (%)	
Uneducated	48 (13.0)
Primary–middle school	57 (15.4)
High school or diploma	79 (21.4)
Graduate or professional	184 (49.7)
Missing	2 (0.5)
Employment Status, n (%)	
Unemployed	134 (36.2)
Blue collar	112 (30.3)
White collar	111 (30.0)
Missing	13 (3.5)
Monthly Family Income [in US Dollars] n (%)	
$\leq 80$	74 (20.0)
81–200	43 (11.6)
201–549	24 (6.5)
$\geq 550$	152 (41.1)
Missing	77 (20.8)
Household Socioeconomic Status *, n (%)	
Low	213 (57.6)
High	157 (42.4)

1 US Dollar = approximately 65.69 Indian Rupees (average currency exchange rate, January–April 2015)

\*Socioeconomic status classification and cut-off values are from a validated composite scale developed for India. The scale measures three variables – education, occupation of the head of the household and income of the family – that are relevant to the Indian context. (Gururaj 2014).

**Table 2.** Anthropometric characteristics of participants by gender and income.

Body Mass Index (BMI) Categories <sup>a</sup> n (%)	Overall	Gender		Household Income	
		Male	Female	Low	High
Underweight	35 (9.5)	8 (4.8)	27 (13.6)	9 (4.2)	26 (16.6)
Normal weight	177 (47.8)	92 (55.4)	84 (42.2)	107 (50.2)	70 (44.6)
Overweight	77 (20.8)	37 (22.3)	39 (19.6)	54 (25.4)	23 (14.6)
Obese	47 (12.7)	15 (9.0)	31 (15.6)	31 (14.6)	16 (10.2)
Missing	34 (9.2)	14 (8.4)	18 (9.0)	12 (5.6)	22 (14.0)

<sup>a</sup>The World Health Organization principal cut-off points for BMI were used to create the categories: underweight (<18.5 kg/m<sup>2</sup>), normal weight (18.5–24.99 kg/m<sup>2</sup>), overweight (25–24.99 kg/m<sup>2</sup>) and obese (≥30 kg/m<sup>2</sup>) (World Health Organization 2000).

**Table 3.** BMI, moderate-to-vigorous physical activity and sedentary levels observed at walkability categories.

Neighbourhood Walkability Characteristics <sup>a</sup>	Body Mass Index (BMI) <sup>b</sup> Mean (SD)	Overweight or Obese n (%)	Weekly MVPA <sup>c</sup> in minutes Mean (SD)	Weekly Sitting Time in minutes Mean (SD)
Residential Density				
Low	25.5 (5.8)	70 (37.2%)	203.0 (355.4)	379.5 (269.7)
High	23.7 (5.4)	54 (29.7%)	254.8 (350.4)	366.2 (252.5)
Land-use Mix Diversity				
Low	24.9 (5.2)	102 (36.2%)	221.3 (302.8)	404.5 (266.9)
High	23.5 (6.7)	22 (25.0%)	251.8 (486.1)	270.4 (212.3)
Land-use Mix Access				
Low	24.3 (7.2)	28 (29.8%)	261.2 (456.6)	358.7 (246.8)
High	24.7 (5.0)	96 (34.8%)	217.6 (312.4)	377.8 (266.1)
Street Connectivity				
Low	23.7 (5.8)	21 (25.0%)	216.4 (462.5)	222.7 (196.7)
High	24.8 (5.6)	103 (36.0%)	231.6 (318.9)	415.6 (261.7)
Walking and Bicycling Infrastructure				
Low	24.7 (5.8)	105 (34.7%)	235.0 (368.3)	367.5 (260.5)
High	23.8 (5.1)	19 (28.4%)	196.3 (270.7)	398.1 (264.6)
Aesthetics				
Low	24.5 (5.7)	96 (33.8%)	253.9 (380.0)	370.6 (255.0)
High	24.6 (5.7)	28 (32.6%)	126.0 (185.3)	381.1 (282.9)
Safety from Traffic				
Low	24.8 (5.5)	92 (35.9%)	216.8 (305.9)	371.1 (256.4)
High	24.0 (6.0)	32 (28.3%)	256.2 (448.4)	378.4 (273.8)
Safety from Crime				
Low	23.9 (5.4)	62 (30.5%)	247.0 (397.5)	322.3 (231.5)
High	25.5 (5.9)	62 (37.9%)	207.4 (291.6)	434.5 (282.8)

<sup>a</sup>All subscales were positively scored to ensure that a higher score denoted a more activity-friendly neighbourhood. All subscales were dichotomized. Residential density was dichotomized into low (weighted mean ≤ 545) and high (weighted mean > 545) densities. Land-use mix-diversity was dichotomized into ≤10 min or ≥10 min walking distance. Four-point Likert-type scale response options for all other subscales (land use mix-access, street connectivity, walking and bicycling infrastructure, aesthetics, safety from traffic and safety from crime) ranging from 1 (strongly agree) to 4 (strongly disagree) were combined as 'agree' (strongly agree, agree) and 'disagree' (disagree, strongly disagree)

<sup>b</sup>SD = Standard Deviation

<sup>c</sup>MVPA = Moderate-to-Vigorous Physical Activity

categories. Moderate-to-vigorous physical activity was higher in neighbourhoods with higher residential density (Mean = 254.8 min/week, SD = 350.4 min/week), land-use mix diversity (Mean = 251.8 min/week, SD = 486.1 min/week), street connectivity (Mean = 231.6 min/week, SD = 318.9 min/week) and safety from traffic (Mean = 256.2 min/week, SD = 448.4 min/week). Numbers of overweight or obese participants were lower in neighbourhoods with higher residential density (n = 54, 29.7%), land-use mix diversity (n = 22, 25.0%), walking and cycling infrastructure (n = 19, 28.4%) and safety from traffic (n = 32, 28.3%).

Participants from households of low-socioeconomic status were more likely to be overweight/obese (OR = 1.8, 95% CI = 1.1–2.9) than participants from households of high-socioeconomic status. Active commuting was associated with reduced likelihood of overweight or obesity compared to driving to work (OR = 2.9, 95% CI = 1.3–6.4), but this relationship did

not remain significant in adjusted models (aOR = 2.6, 95% CI = 0.7–9.3). Household car ownership was associated with an increase in the likelihood of overweight or obesity (aOR = 1.5, 95% CI = 0.7–3.2) although this relationship was not significant. In unadjusted models, a low walkability neighbourhood significantly predicted an increase in odds of overweight or obesity (OR = 1.8, 95% CI = 1.1–2.8), but this was not significant in adjusted models (OR = 1.7, 95% CI = 0.9–2.9).

## Discussion

This study is one of the first to explore the neighbourhood environment correlates of obesity and overweight among urban residents in India. Impacts of the physical and social environment on obesity and overweight have been examined in recent epidemiological literature; however, there is a paucity of research on the environmental correlates of obesity from South Asia, despite a significant portion of the

**Table 4.** Factors associated with overweight or obesity.

Factor	OR	95% CI	p-value	B value	Pseudo R <sup>2</sup>	aOR*	95% CI	p-value	B value	Pseudo R <sup>2</sup>
Age (Ref: 18–35 years)										
>35 years	3.0	1.9–4.7	0.000	1.1	0.1	n/a	n/a	n/a	n/a	n/a
Gender (Ref: Female)										
Male	1.2	0.8–1.9	0.4	0.2	0.0	n/a	n/a	n/a	n/a	n/a
Household socio-economic status (Ref: High)										
Low	1.8	1.1–2.9	0.01	0.6	0.0	n/a	n/a	n/a	n/a	n/a
Household car/motor vehicle ownership (Ref: No)										
Yes	1.5	0.7–3.2	0.3	0.4	0.0	n/a	n/a	n/a	n/a	n/a
Distance to work (Ref: Distance ≤ 10 km)										
Distance > 10 km	1.1	0.6–2.1	0.8	0.1	0.0	0.7	0.4–1.5	0.4	–0.3	0.2
Use public transit to commute to work (Ref: Yes)										
Car Driving	1.1	0.6–2.3	0.7	0.1	0.0	0.7	0.3–1.8	0.5	–0.3	0.2
Actively commute to work (Ref: Yes)										
Car Driving	2.9	1.3–6.4	0.008	1.1	0.1	2.6	0.7–9.3	0.1	1.0	0.2
Public transit stops within 10-minute walk (Ref: Yes)										
No transit stop	0.5	0.3–0.9	0.01	–0.6	0.0	0.6	0.3–1.3	0.2	–0.4	0.2
Meeting physical activity recommendations <sup>a</sup> (Ref: Yes)										
No	1.1	0.7–1.8	0.7	0.1	0.0	0.9	0.5–1.7	0.8	–0.1	0.2
Time spent sitting weekly (Ref: Low, ≤ 60 minutes/day)										
High	1.2	0.8–1.9	0.5	0.2	0.0	1.2	0.7–2.0	0.6	0.1	0.2
Neighbourhood walkability score (Ref: High)										
Low	1.8	1.1–2.8	0.01	0.6	0.0	1.7	0.9–2.9	0.07	0.5	0.2

OR = Unadjusted Odds Ratios, aOR = Adjusted Odds Ratios, CI = Confidence Interval.

<sup>a</sup>At least 150 minutes of physical activity per week based on global recommendations for physical activity among adults established by the World Health Organization.

\*Adjusted for age, gender, household socioeconomic status and household car ownership

obesity disease burden being concentrated on the region (Bassett *et al.* 2008, Heath *et al.* 2012, Bauman *et al.* 2013, Becerra *et al.* 2013). We found that walkable neighbourhoods were associated with higher levels of physical activity and lower odds of obesity/overweight. Residents living in neighbourhoods with a diversity of destinations, availability of walking and bicycling facilities were more likely to meet physical activity recommendations. Active commuting was associated with lower odds of being overweight or obese. These results raise the possibility that built environment attributes found to facilitate active commuting in higher-income countries do not fully generalize to low- and middle-income countries. Findings from this study in urban India emphasize the need for more high-quality epidemiologic studies from low- and middle-income countries.

In our analyses, driving to work predicted a three-fold increase in overweight or obesity compared to active commuting in unadjusted models, but this relationship did not remain significant in adjusted models. Previous studies have highlighted that active commuting could reduce the detrimental effect of obesity and could potentially decrease the risk of premature mortality (Gordon-Larsen *et al.* 2005, Yang *et al.* 2015). Research has also shown that residents in walkable, activity-friendly neighbourhoods, such as well-connected streets, tree-shaded sidewalks, pleasant aesthetic features and transit access have higher levels of active commuting and a lower prevalence of obesity (Sallis *et al.* 2020). Active commuting is specifically associated with improved physical fitness, weight

control, reduced cardiovascular risk and lower obesity (Yang *et al.* 2015). Despite these benefits, urban India is witnessing inadequate development of public transport infrastructure, hazardous conditions for walking and bicycling, and a mass adoption of private motorized vehicles (Ministry of Urban Development (MOUD) 2013, Ministry of Road Transport and Highways, 2010–2011, Pucher *et al.*, 2007, Solanki *et al.* 2016).

Previous research from India has highlighted that urban living is associated with lower transport physical activity and increasingly sedentary lifestyles (Adlakha *et al.* 2016b). All of these factors are likely contributing to declining levels of active commuting and a rise in population prevalence of overweight, obesity and related non-communicable diseases in India. This is important given that India's urban planning models lack suitable policies to manage growth (Mohanty 2014) which has resulted in urban sprawl and traffic congestion, made worse by inadequate quality and safety of public transport and non-motorised transport infrastructure (Chatterjee and Chattopadhyay 2020). As Indian cities expand and car ownership increases, pedestrians are being marginalised and their safety is likely being put at risk.

Studies have suggested that variations in physical activity and obesity prevalence may be driven by income or education, although patterns might differ across countries. Previous studies on associations between socioeconomic status and obesity concluded that obesity was essentially a disease of the socioeconomic elite in low- and middle-income

countries, in contrast to the situation in developed countries where obesity was more common among the poor than among the rich (Ogden *et al.* 2017). However, recent research has shown that the burden of obesity is shifting toward the poor in developing societies (Monteiro *et al.* 2007). Findings from this study confirmed this trend with participants from low-socioeconomic status households more likely to be overweight or obese. There are multiple individual and environmental factors that may explain why populations in neighbourhoods of low-socioeconomic status are less active and bear greater obesity burdens. One reason may be that parks, green spaces and playgrounds are less available to people living in poor neighbourhoods, thereby limiting opportunities for physical activity (Sallis *et al.* 2011). Low-income populations may be less able to afford indoor exercise equipment and/or memberships to gyms, sport facilities and recreation centres. Neighbourhoods with higher poverty rates also tend to experience higher levels of crime and violence, which can deter physical activity (Rees-Punia *et al.* 2018).

Socioeconomic characteristics are associated with physical activity levels, and this is especially true of car ownership. In this study, motor vehicle ownership demonstrated a strong association with obesity and overweight in unadjusted models, which confirms previous research. Findings from low- and middle-income countries like Mexico, Colombia and Nigeria have shown that motor vehicle ownership is inversely associated with transport-based physical activity and a predictor of obesity (Parra *et al.* 2009, Salvo *et al.* 2015, Oyeyemi *et al.* 2016a). Studies have shown that non-vehicle owners tend to have higher levels of transport-based physical activity levels, which may be strongly driven by necessity rather than choice. As automobile ownership increases across the developing world and has become the primary mode of transportation, the built environment has evolved such that walking, bicycling and other forms of active travel are difficult and even hazardous (Shoham *et al.* 2015). More research is needed to understand and assess socio-economic factors and their relationship with active commuting across larger geographical areas and over extended periods of time in low- and middle-income country contexts in South Asia.

### Strengths and limitations

The cross-sectional study design limits causal inference and the relatively small sample from a single city in India may restrict the generalizability of these results. Further, the possibility of residual confounding and self-selection (i.e. individuals who prefer active lifestyles may select to live in areas that are more conducive to walking, bicycling and active travel

modes) are limitations of this study. Self-reported measures such as IPAQ and NEWS are prone to bias from social desirability, recall period, sampling approach, or selective recall (Wood 2000).

In recent studies, researchers have independently weighed and measured participants to calculate BMI and used accelerometers to track physical activity. These methods can provide objective data; however, self-reported anthropometric data are commonly used to estimate the prevalence of obesity in population and community-based studies of this nature (Bowring *et al.* 2012). A key limitation of studies in this area is a lack of consensus on the measurement of physical activity domains and types of activity in each domain, reliability and validity of questionnaires to measure domain-specific physical activity, and the inability to compare results across studies due to the large number of measures available (Steele and Mummery 2003). This study did not investigate the relationship between dietary patterns and body weight, which may be a key factor contributing to the risk of overweight and obesity in Indian populations. Studies have investigated links between consumption of high glycaemic diets and susceptibility to obesity, diabetes and non-communicable diseases in some regions of India; however, the findings are mixed (Joy *et al.* 2017). Despite the limitations, this study fills a critical gap in the scientific literature to resolve the problematic and urgent implications for population physical activity and public health in an urban South Asian context.

### Conclusions

As the global burden of disease shifts from infectious diseases to non-communicable diseases in South Asia, an understanding of how environmental factors affect obesity and how best to influence them are important for public health, health equity and urban planning. By 2030, Indian cities are projected to be home to another 250 million people alongside a 9.9% annual growth rate in motor vehicles. The health and socio-economic implications from this heavy reliance on motorised transportation are likely to be substantial, running into tens of billions of dollars every year (Shoham *et al.* 2015, Adlakha *et al.* 2018). Similar patterns of rapid urban growth and motorised traffic are being witnessed across South Asia and potential concerns with respect to declining physical activity levels, reduced road safety, worsening air pollution and traffic congestion. Low- and middle-income countries in South Asia have a particularly high reliance on private automobiles compared to other parts of the world, with higher rates of car usage and ownership reported in Indonesia, Cambodia, the Philippines and Vietnam (The Organisation for Economic Co-operation and Development 2018).

As car ownership increases across South Asia, extra efforts may be needed to ensure population levels of physical activity. The documented harms of high automobile use such as lung diseases from air pollution, higher non-communicable disease risk due to the inactivity during vehicle use, and injury and death from traffic crashes must be considered (Douglas *et al.* 2011, Giles-Corti *et al.* 2016). Building infrastructure that supports active commuting and equitable transit access can promote physical activity (Sallis *et al.* 2020). City planners, public health practitioners, and elected officials need to design policies and programs that reach all members of society, especially the poor. Designing walkable communities may enable people at all income levels to travel to work, to school and for daily needs using active transport modes. Walkable, activity-friendly neighbourhoods can also enable people with long-distance work commutes to reduce non-work automobile travel that increases non-communicable disease risk (Vancampfort *et al.* 2018, Sallis *et al.* 2020). It is also important for future studies in South Asia to investigate the role of diet, nutrition and physical activity in order to achieve the best results in preventing non-communicable diseases. Systematic attention to measuring social, cultural and built environments could lead to improved understanding of their role in enhancing or inhibiting physical activity and the development of context-specific interventions to increase population levels of physical activity.

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### Disclosure statement

No potential conflict of interest was reported by the authors.

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