Research Article

Association between Perceived Built Environment and Prevalent Hypertension among South African Adults

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Introduction. The association between perceived built environmental attributes and hypertension among adults has received little attention in an African context. We investigated the association between the perceived built environment and prevalent hypertension in adult South Africans. **Method.** A cross-sectional study was conducted using 2008-2009 Prospective Urban Rural Epidemiology data among South African ($n = 671$) adults aged ≥ 35 years. Perceived built environment was assessed using the neighborhood environment walkability scale questionnaire. Prevalent hypertension was defined as previously diagnosed by a physician, screen-detected hypertension as $\geq 140/90$ mmHg, and a combination of both as any hypertension. Logistic regressions were applied for analyses. **Results.** In crude logistic regressions, self-reported hypertension was associated with land use mix-diversity, street connectivity, infrastructure for walking/cycling, aesthetics, traffic, and crime. In adjusted model, land use mix-diversity was significantly associated with self-reported hypertension. In similar multivariable models, the direction and magnitude of the effects were mostly similar to the outcomes of “screen-detected hypertension” which was further predicted by perceived lack of safety from traffic. **Conclusion.** Perceived built environment attributes were significantly associated with hypertension. This has relevance to population-based approaches to hypertension prevention and control.

1. Background

Hypertension is estimated to cause 7.5 million premature deaths, accounting for 12.8% of all global deaths annually [1]. Hypertension is associated with an increased risk of morbidity and mortality from cardiovascular disease (CVD) [2], with high event rates occurring in low- and middle-income countries [3] and greater than 50% increased prevalence expected from 2000–2025 [4]. South Africa is experiencing a demographic and epidemiological transition with an increase in the population aged 50 years and older and rising prevalence of noncommunicable diseases [5]. Hypertension is a common condition in South Africa and is a risk factor for heart attacks and stroke [6]. In 2000, high blood pressure

was estimated to have caused 9% ($n = 46888$) of all deaths and 2.4% ($n = 390860$) of all disability-adjusted life years [7] among South Africans. According to van de Vijver et al. [8], hypertension has been regarded as a disease of affluence but this has changed drastically in the last two decades with average blood pressure now higher in Africa than in the Global North and the prevalence of hypertension increasing among poor sections of the society. For example, in a recent systematic review and meta-analysis conducted in Sub-Saharan Africa, the prevalence of hypertension ranged from 15% to 70% [9].

Various risk factors have been associated with hypertension [10, 11]. However, in order to reduce the burden of CVD risk factors, environmental interventions have become

increasingly recognized as necessary approaches to support behavior change [12]. The fundamental attributes of built environments and community design [13, 14] have been linked with increased risk of hypertension and cardiovascular events [15], but only a few studies have evaluated these relationships in an African context [16]. Thus, this study evaluates the association between perceived built environment attributes and the prevalence of hypertension in South African adults in both an urban (Cape Town) and a rural (Mount Frere) context. Our focus was on the general perception of built environment attributes rather than components of it.

2. Methods

2.1. Study Population. This cross-sectional study uses data from Cape Town (urban) and Mount Frere (rural) sites of the global Prospective Urban Rural Epidemiology (PURE) study. During baseline evaluation conducted in 2008-2009, a random sample of both male and female adults was selected from well-established rural (Mount Frere, $N = 1003$) and urban (formal settlements in Cape Town, $N = 1061$) communities in South Africa. The inclusion criteria for participants were those (1) aged 35–70 years, (2) living within identified household, and having (3) no disability that precluded walking.

2.2. Ethical Considerations. The study was conducted according to the Helsinki principles [17]. The Senate Higher Degrees committee, Research Committees of the University of the Western Cape, South Africa, and Population Health Research Institute, Canada, approved the study (Registration #13/6/18). A consent form was signed by all the participants.

2.3. Data Collection. Participants were interviewed in the language of their choice. Structured, sociodemographic, and lifestyle questionnaires that were developed or adapted and standardized for the international PURE study were used [18]. Physical examination included anthropometric measures [19]. The NEWS was used to assess perceived neighborhood environment.

2.4. Sociodemographic Characteristics. Sociodemographic information on age, sex, marital status, education level, location, and occupation was elicited from participants. Participants' age was grouped into 3 categories: 35 to 44 years, 45 to 54 years, and 55 and above. Marital status was classified as single, married, and divorced. Education level was classified as primary, secondary, and tertiary education. Occupation was categorized into 2 groups: less skilled (artisan, trader, farmer, etc.) and homemaker. Smoking was defined as former smoker, current smoker, and never smoked. In this analysis, former and current smoker were categorized as "yes" and never smoker was categorized as "no." Alcohol use was treated in the same way as smoking.

2.5. Anthropometric and Biological Measures. Body height and body weight were determined by standard anthropometric methods. Height was measured to the nearest 0.1 cm in bare feet with participants standing upright using a portable tape measure. Weight was measured to the nearest kilogram, with participants lightly dressed using a portable bathroom weighing scale calibrated (Soehnle, Germany) from 0 to 120 kg. Body mass index (BMI) was calculated as weight (kg) divided by the square of the height (m^2). The World Health Organization [20] principal cut-off points for BMI were used to create the categories: underweight ($<18.5 \text{ kg}/m^2$), normal weight ($18.5\text{--}<25 \text{ kg}/m^2$), overweight ($25\text{--}<30 \text{ kg}/m^2$), and obese ($>30 \text{ kg}/m^2$).

2.6. Blood Pressure Measurement and Definition of Hypertension. Trained staff measured blood pressure using an OMRON 711 automated device with the appropriate cuff size for the measured mid-upper-arm circumference and after the subject had been seated at rest for at least 10 minutes. Two readings were made 3-4 minutes apart and the averaged reading was used for the definition of hypertension [21]. Additionally, hypertension was defined as previously diagnosed hypertension by a physician based on a positive answer to the question "have you been diagnosed with hypertension?" for self-reported hypertension. Screen-detected hypertension was defined as blood pressure $\geq 140/90$ mmHg among those with no prior diagnosis of hypertension, while "any hypertension" was based on the presence of self-reported or screen-detected hypertension.

2.7. Self-Reported Physical Activity. The long version of the International Physical Activity Questionnaire (IPAQ), which is self-administered, was used to measure sedentary, light, moderate, and vigorous intensity activities and walking in terms of the frequency (days/week) and duration (min/day) in the last 7 days. Only activities lasting for 10 consecutive minutes or more were considered [22]. A cut-off point of 150 minutes per week was used to classify subjects as sufficiently physically active or physically inactive [23] and used previously [22]. Acceptable reliability and validity of IPAQ have been reported elsewhere [24].

2.8. Perceived Built Environment. The neighborhood environment walkability scale (NEWS) questionnaire was used to obtain perceived neighborhood attributes for each participant. Participants were instructed to consider neighborhood as the area within a 10–15 min walk from their home and answered questions pertaining to the following subscales: (a) land use mix-diversity (*having commercial destinations within walking distance, 10 items*); (b) land use-access (*the ease of access from one's home to activity opportunities, 4 items*); (c) streets connectivity (*the number of 3- and 4-way intersections in a an area/total area in squared kilometers, 3 items*); (d) infrastructure for walking and cycling (*the maintenance, existence of sidewalks, and layout of roads, 3 items*); (e) aesthetics (*attractions and cleanness of neighborhoods, 3 items*); (f) safety from traffic (*traffic condition and its negative effect on environment, 3 items*); (g) safety from crime (*perceived*

TABLE 1: Subscales and sample item description from the neighborhood environment walkability scale.

Item number	Subscale	Sample item description
01	Land use mix-diversity	About how long would it take to get from your home to the <i>nearest</i> businesses or facilities if you <i>walked</i> to them? (i) Groceries (ii) Clothes shop (iii) Fruits and vegetables (iv) Restaurant (v) Bank (vi) Video shop
02	Land use-access	I can do most of my shopping at local stores Stores are within easy walking distance of my home There are many places to go within easy walking distance of my home It is easy to walk to a transit stop from my home
03	Streets connectivity	The distance between intersections in my neighborhood is usually short There are many four-way intersections in my neighborhood There are many alternative routes for getting from place to place in my neighborhood
04	Infrastructure for walking/cycling	There are sidewalks on most of the streets in my neighborhood The sidewalks in my neighborhood are well maintained There is a grass/dirt strip that separates the streets from the sidewalks in my neighborhood
05	Aesthetics	Trees give shade for the sidewalks in my neighborhood There are many interesting things to look at while walking in my neighborhood My neighborhood is generally free from litter
06	Safety from traffic	There is so much traffic along the street I live on that it makes it difficult or unpleasant to walk in my neighborhood There is so much traffic along nearby streets that it makes it difficult or unpleasant to walk in my neighborhood The crosswalks in my neighborhood help walkers feel safe crossing busy streets
07	Safety from crime	My neighborhood streets are well lit at night The crime rate in my neighborhood makes it unsafe to go on walks during the day The crime rate in my neighborhood makes it unsafe to go on walks at night

fear in the neighborhood, 3 items). All items except for the land use mix-diversity subscale were scaled from 1 (strongly disagree) to 4 (strongly agree), with higher scores indicating more favorable rating. For statistical analyses, however, we collapsed these variables into two categories of agree (1 = 1 or 2) or disagree (2 = 3 or 4) [25]. Land use mix-diversity was assessed by asking for the time taken to walk from home to various types of stores and facilities, with responses ranging from 1- to 5-minute walking distance (coded as 5) to ≥ 30 -minute walking distance (coded as 1). The land use mix-diversity variables were dichotomized into " ≤ 20 minutes" and " ≥ 21 minutes" for analyses purposes [26]. Higher scores on land use mix-diversity indicated closer average temporal proximity. All subscale scores were calculated as the mean across the subscale items. Items with inverse interpretation were reverse coded for analyses, with higher values reflecting environmental attributes hypothesized to be conducive to physical activity [27]. Sample items from the NEWS are described in Table 1. NEWS has been shown to be both a valid and reliable means of assessment [28].

2.9. Statistical Analysis. The starting sample comprised 1016 participants of whom 345 were excluded for unacceptable missing data [29] after merging of three datasets. Therefore, the final analytic sample comprised 671 participants with

a complete NEWS questionnaire. Data analysis used SPSS® version 22 for Windows (IBM Corp., Armonk, New York). Descriptive statistics were computed for all variables. The Chi squared test was used to compare sociodemographic characteristics selected CVD risk factors and built environment attributes by gender. Logistic regressions were used to investigate the determinants of hypertension. In order to identify factors associated with hypertension, two models were fitted. Model 1 (crude odd ratios) determined the association between sociodemographic characteristics, selected CVD risk factors, and built environment attributes by gender. Model 2 (adjusted odd ratios) determined the association between built environment attributes after adjusting for sociodemographic (sex, age, location, and education status), BMI, and physical activity variables. The main analyses were focused on the outcome of "self-reported hypertension." However, in secondary analyses we also explored the effects on the outcomes of "screen-detected hypertension" and "any hypertension."

3. Results

3.1. General Characteristics of the Participants. Table 2 depicts the overall sociodemographic characteristics, selected CVD risk factors, and perceived built environment attributes of

TABLE 2: Sociodemographic characteristics of participants.

Variable	Female (<i>n</i> = 510) Number (%)	Male (<i>n</i> = 161) Number (%)	<i>p</i> value	All (<i>n</i> = 671) Number (%)
<i>Gender</i>				
Female				510 (76.0)
Male				161 (24.0)
<i>Age</i>			0.251	
35–44	173 (33.9)	48 (29.8)		221 (32.9)
45–54	166 (32.5)	63 (39.1)		229 (34.1)
55+	171 (33.5)	50 (31.1)		221 (32.9)
<i>Marital status</i>			0.001	
Single	209 (41.0)	56 (34.8)		265 (39.1)
Married	192 (37.6)	85 (52.8)		277 (41.3)
Divorce	109 (21.4)	20 (12.4)		129 (19.2)
<i>Education status</i>			0.140	
Primary	17 (3.3)	11 (6.8)		28 (4.2)
Secondary	471 (92.4)	142 (88.2)		613 (91.4)
Tertiary	22 (4.3)	8 (5.0)		30 (4.5)
<i>Occupation</i>			0.118	
Less skilled	75 (14.7)	129 (80.1)		564 (84.1)
Homemaker	435 (85.3)	32 (19.9)		107 (15.9)
<i>Ethnicity</i>			0.240	
African	506 (99.2)	158 (98.1)		664 (99.0)
Coloured	4 (0.8)	3 (1.9)		7 (1.0)
<i>Location</i>			0.915	
Urban	221 (43.3)	69 (42.9)		290 (43.2)
Rural	289 (56.7)	92 (57.1)		381 (56.8)
<i>Selected CVD risk factors</i>				
<i>Blood pressure (<i>M</i> ± <i>SD</i>)*</i>				
Systolic blood pressure (mmHg)	142.2 (25.7)	140.5 (19.4)	0.838	141.8 (24.2)
Diastolic blood pressure (mmHg)	92.7 (15.2)	89.3 (12.2)	0.004	91.9 (14.6)
<i>Self-reported hypertension</i>				
No	338 (66.3)	134 (83.2)	<0.001	472 (70.3)
Yes	172 (33.7)	27 (16.8)		199 (29.7)
<i>Screen-detected hypertension</i>				
Normotension	186 (55.0)	38 (28.4)	<0.001	224 (47.5)
Hypertension	152 (45.0)	96 (71.6)		248 (52.5)
<i>Any hypertension</i>				
No	186 (36.5)	38 (23.6)	0.003	224 (33.4)
Yes	234 (63.5)	123 (76.4)		447 (66.6)
<i>Self-reported diabetes</i>				
No	466 (91.4)	150 (93.2)	0.469	616 (91.8)
Yes	44 (8.6)	11 (6.8)		55 (8.2)
<i>BMI category</i>				
Normal	100 (19.6)	107 (66.4)	<0.001	207 (30.8)
Overweight	127 (24.9)	23 (14.3)		150 (22.4)
Obese	283 (55.5)	31 (19.3)		314 (46.8)
<i>Smoking</i>				
No	437 (85.7)	70 (43.5)	<0.001	507 (75.6)
Yes	73 (14.3)	91 (56.5)		164 (24.4)
<i>Alcohol use</i>				
No	448 (87.8)	73 (45.3)	<0.001	521 (77.6)
Yes	62 (12.2)	88 (54.7)		150 (22.4)

TABLE 2: Continued.

Variable	Female (n = 510) Number (%)	Male (n = 161) Number (%)	p value	All (n = 671) Number (%)
<i>Physical activity levels</i>			0.718	
<150 min/week	152 (30.8)	52 (32.3)		209 (31.1)
>150 min/week	353 (69.2)	109 (67.7)		462 (68.9)
<i>Perceived built environment attributes</i>				
<i>Land use mix-diversity</i>			0.110	
≤20 min	42 (8.2)	20 (12.4)		62 (9.2)
≥21 min	468 (91.8)	141 (87.6)		609 (90.8)
<i>Land use mix-access</i>			0.160	
Disagree	381 (74.7)	129 (80.1)		510 (76.0)
Agree	129 (25.3)	32 (19.9)		161 (24.0)
<i>Street connectivity</i>			0.612	
Disagree	227 (44.5)	68 (42.2)		295 (44.0)
Agree	283 (55.5)	93 (57.8)		376 (56.0)
<i>Infrastructure for walking/cycling</i>			0.091	
Disagree	248 (48.6)	66 (41.0)		314 (46.8)
Agree	262 (51.4)	95 (59.0)		357 (53.2)
<i>Aesthetics</i>			0.082	
Disagree	318 (62.4)	88 (54.7)		406 (60.5)
Agree	192 (37.6)	73 (45.3)		265 (39.5)
<i>Safety from traffic</i>			0.490	
Disagree	263 (51.6)	78 (48.8)		341 (50.8)
Agree	247 (48.4)	83 (51.6)		330 (49.2)
<i>Safety from crime</i>			0.172	
Disagree	234 (45.9)	64 (39.8)		298 (44.4)
Agree	176 (54.1)	97 (60.2)		373 (55.6)

SD: standard deviation; * subsample of 472 participants after excluding those with self-reported hypertension.

participants. Out of 671 participants, 76.0% were women, 32.9% were aged 35–44 years, and 56.8% were from the rural site. Overall, 41.3% of the participants were married and marital status differed by gender ($p = 0.001$). The study population comprised 99.0% Africans and 1.0% mixed-ancestry participants. There were significant gender differences in the distribution of BMI categories, smoking, and alcohol use (all $p < 0.001$). The majority (68.9%) of the participants met physical activity guidelines and there was no gender difference ($p = 0.718$). Overall the distribution of perceived built environment attributes was as follows: land diversity (≥ 20 min) 90.8%, land access (disagreed) 76.0%, street connectivity (agreed) 56.0%, walking/cycling (agreed) 53.2%, aesthetics (disagreed) 60.5%, safety from traffic (disagreed) 50.8%, and crime (agreed) 55.6%. These differences were not significant across gender (all $p > 0.05$; Table 2).

3.2. Prevalent Hypertension. A total of 199 participants reported a previous diagnosis of hypertension. Therefore, the overall prevalence of self-reported diagnosed hypertension was 29.7%. Equivalent figures were 33.7% in women and

16.8% in men. The difference in the prevalence of self-reported hypertension between men and women was significant ($p < 0.001$ Table 2). Among those with no prior hypertension ($n = 472$), 248 (52.5%) met the diagnostic threshold for “screen-detected hypertension” while 447 (66.6%) of the total sample had any hypertension. The prevalence of screen-detected hypertension ($p < 0.001$) and “any hypertension” ($p = 0.003$) was always higher in men than in women (Table 2).

Overall, among those with no prior hypertension, the mean blood pressure level was 141.8 ± 24.2 mmHg (systolic) and 91.9 ± 14.6 mmHg (diastolic). Equivalent figures were 142.2 ± 25.7 mmHg (systolic) and 92.7 ± 15.2 mmHg (diastolic) in women and 140.5 ± 19.4 mmHg (systolic) and 89.3 ± 12.2 mmHg (diastolic) in men (Table 2). Differences in mean BP by gender were significant for diastolic blood pressure ($p = 0.004$), but not for systolic blood pressure ($p = 0.838$; Table 2).

3.3. Association between Sociodemographic Characteristics, CVD Risk Factors, Perceived Built Environment Attributes, and Self-Reported Hypertension. In general, univariate analysis

indicates that women were more likely to be at risk of hypertension (OR = 2.53, 95% CI = 1.61–3.97) compared to their male counterparts. Overall, those aged 45–54 years (OR = 3.86, 95% CI = 2.26–6.57) and those aged 55 and above were more likely to be at risk of hypertension than those aged 35–44 years (OR = 9.79, 95% CI = 5.81–16.48). Divorced persons ((relative to the single) results not shown) were more likely to report hypertension (OR = 2.44, 95% CI = 1.51–3.94; Table 3). Urban dwellers were at higher risk of hypertension (OR = 2.26, 95% CI = 1.61–3.16) compared to those in rural areas. Those who were overweight (OR = 2.42, 95% CI = 1.45–4.04) and obese (OR = 3.43, 95% CI = 2.21–5.32) were at greater risk of hypertension. There was no significant association between PA and hypertension ($p > 0.05$).

3.4. Association between Perceived Built Environment and Self-Reported Hypertension. In the overall sample, the odds of hypertension were significantly higher in persons who reported that distances to neighborhood destinations required walking more than 21 minutes (OR = 1.96, 95% CI = 1.51–3.34; Table 3). Those who perceived that their streets were well connected had lower odds of hypertension (OR = 0.53, 95% CI = 0.37–0.74). Those who perceived their infrastructure was good for walking and cycling (OR = 0.65, 95% CI = 0.46–0.90) and those who perceived their neighborhood aesthetics to be of good quality were less likely to report diagnosed hypertension (OR = 0.71, 95% CI = 0.51–0.90). Those who perceived their environment to be at risk of crime had higher odds of hypertension (OR = 1.44, 95% CI = 1.03–2.02). Perceived lack of safety from traffic was also significantly associated with hypertension (OR = 1.46, 95% CI = 1.04–2.03).

3.5. Multivariable Associations of Perceived Built Environment Attributes with Self-Reported Hypertension. Age, gender, education, location, BMI, and physical activity-adjusted associations between perceived built environment attributes and self-reported hypertension are shown in Table 3. Those who perceived that the distance between their residences and the nearest destination (land use mix-diversity) was more than 21 minutes had higher odds (expected direction) of self-reported hypertension (OR = 2.37, 95% CI = 1.24–4.55). However, street connectivity, infrastructure for walking/cycling, aesthetics, and safety from traffic and crime were no longer significantly associated with the outcome ($p > 0.05$).

3.6. Multivariable Associations of Perceived Built Environment with Screen-Detected Hypertension and Any Hypertension. The multivariable associations of perceived built environment attributes with screen-detected hypertension and any hypertension are shown in Table 4. After adjusting for age, gender, education, location, BMI, and physical activity, only perceived lack of safety from traffic was associated with screen-detected hypertension (OR = 1.89, 95% CI = 1.07–2.02) while other perceived built environment attributes were not statistically significant in both screen-detected hypertension and any hypertension ($p > 0.05$).

4. Discussion

The prevalence of hypertension among this sample of urban and rural adult South Africans was high, with nearly one-third reporting existing hypertension and about two-thirds having either self-reported or screen-detected hypertension. In crude logistic regressions, self-reported hypertension was associated with land use-mix, street connectivity, infrastructure for walking/cycling, aesthetics, traffic, and crime. In the adjusted models, land use mix-diversity was significantly associated with self-reported hypertension and to some extent with screen-detected hypertension. Lack of safety from traffic was further associated with screen-detected hypertension. To our knowledge, this is the first study in South Africa that has attempted to explore the association between perceived neighborhood environment attributes and prevalent hypertension.

In our simple logistic regression model, land use mix-diversity (proximity) was associated with hypertension. In another cross-sectional study similar results were found [30]. A possible potential mechanism suggested that the benefit of living near to public facilities would include increased recreational physical activity and seeing others, which encourages the frequency of walking, that in turn lower the risk of developing hypertension. In addition, we observed that street connectivity in the neighborhood was associated with hypertension. There is very scant literature on this field. It has been suggested that research should move beyond evaluating the relationships between the built environment and walking, to chronic disease risk factors and outcomes that relate to walkability as well as more specific characteristics of the built environment [26]. Similarly to our study, other investigators have corresponding results [31]. For instance, Coffee et al. [26] used geographic information system to test the hypothesis that higher walkability index was associated with a lower cardiometabolic risk (CMR) among Australian adults. Their study revealed that a lower CMR score (including hypertension) was associated with higher walkability index. Similarly, Li et al. [32] noted a decrease in systolic and diastolic blood pressure for those living in high walkable neighborhoods. Likewise, Marshall et al. [31] study suggested that more compact and connected street networks with fewer lanes on the major roads were correlated with reduced rates of high blood pressure. A possible explanation for this relationship may be that many alternative routes in the local area increase the possibilities of cycling for recreation or walking which in turn would lower the risk of hypertension.

In our study we found those who perceived that their infrastructure was good for walking and cycling were less likely to be hypertensive which is indicative of healthier lifestyle. One study conducted in USA was in agreement with our study [33]. Likewise, similar results were observed in a cross-sectional study that examined mode and duration of travel to work in rural and urban India and associations between active travel and hypertension [34]. These studies have demonstrated that infrastructure for working and cycling in both low-income countries and high-income countries lowers hypertension risk by promoting walkability. One possible explanation, for instance, is that sidewalk

TABLE 3: Correlates of self-reported hypertension.

Variables	Univariable analysis			Multivariable analysis		
	OR	95% CI	<i>p</i> value	OR ^a	95% CI	<i>p</i> value
<i>Gender</i>						
Male (ref)						
Female	2.53	1.61–3.97	<0.001	2.43	1.41–4.17	<0.001
<i>Age</i>						
35–44 (ref)						
45–54	3.86	2.26–6.57	<0.001	4.39	2.50–7.73	<0.001
55+	9.79	5.81–16.48	<0.001	11.99	6.84–21.01	<0.001
<i>Education level</i>						
Primary (ref)						
Secondary	0.73	0.33–1.61	0.438	0.95	0.38–2.38	0.950
Tertiary	1.20	0.41–3.48	0.737	1.54	0.45–5.26	0.494
<i>Location</i>						
Rural (ref)						
Urban	2.26	1.61–3.16	<0.001	1.74	1.03–2.92	0.038
<i>BMI</i>						
Normal (ref)						
Overweight	2.42	1.45–4.04	0.001	2.00	1.12–3.58	0.019
Obesity	3.43	2.21–5.32	<0.001	2.21	1.32–3.72	0.003
<i>Physical activity level</i>						
<150 min/week (ref)						
>150 min/week	1.23	0.88–1.83	0.203	1.16	0.75–1.79	0.504
<i>Land use mix-diversity</i>						
≤20 min (ref)						
≥21 min	1.96	1.51–3.34	0.013	2.37	1.24–4.55	0.009
<i>Land use mix-access</i>						
Disagree (ref)						
Agree	1.31	0.88–1.96	0.182	0.79	0.43–1.44	0.436
<i>Street connectivity</i>						
Disagree (ref)						
Agree	0.53	0.37–0.74	<0.001	0.64	0.35–1.17	0.149
<i>Infrastructure for walking/cycling</i>						
Disagree (ref)						
Agree	0.65	0.46–0.90	0.011	0.95	0.53–1.72	0.871
<i>Aesthetics</i>						
Disagree (ref)						
Agree	0.71	0.51–0.90	0.049	0.84	0.51–1.37	0.479
<i>Safety from traffic</i>						
Disagree (ref)						
Agree	1.46	1.04–2.03	0.027	1.17	0.66–2.06	0.599
<i>Safety from crime</i>						
Disagree (ref)						
Agree	1.44	1.03–2.02	0.036	1.21	0.72–2.04	0.469

OR: odds ratios; CI: confidence interval; ^aodds ratios adjusted for age, gender, education, location, BMI, and physical activity in the table; bold *p* = significant borderline.

TABLE 4: Multivariable associations of perceived built environment attribute with screen-detected hypertension and any hypertension.

Variables	Screen-detected hypertension			Any hypertension		
	OR ^a	95% CI	p value	OR ^a	95% CI	p value
<i>Gender</i>						
Male (ref)						
Female	0.44	0.28–0.68	<0.001	0.47	0.29–0.78	0.004
<i>Age</i>						
35–44 (ref)						
45–54	1.34	0.85–2.09	0.207	2.06	1.38–3.07	<0.001
55+	3.52	2.04–6.08	<0.001	7.45	4.57–12.16	<0.001
<i>Education level</i>						
Primary (ref)						
Secondary	3.93	0.73–21.14	0.111	3.11	0.67–14.48	0.149
Tertiary	1.12	0.34–3.27	0.830	0.99	0.41–2.36	0.977
<i>Location</i>						
Rural (ref)						
Urban	2.41	1.37–4.24	0.002	2.70	1.64–4.47	<0.001
<i>BMI</i>						
Normal (ref)						
Overweight	1.41	0.85–2.35	0.184	1.41	0.85–2.35	0.184
Obese	1.29	0.76–2.20	0.347	1.29	0.76–2.20	0.347
<i>Physical activity level</i>						
<150 min/week (ref)						
>150 min/week	0.91	0.58–1.43	0.691	0.99	0.66–1.47	0.942
<i>Land use mix-diversity</i>						
≤20 min (ref)						
≥21 min	2.13	0.95–4.75	0.065	1.26	0.67–2.39	0.476
<i>Land use mix-access</i>						
Disagree (ref)						
Agree	0.98	0.55–1.73	0.930	1.02	0.61–1.72	0.928
<i>Street connectivity</i>						
Disagree (ref)						
Agree	0.55	0.30–1.01	0.053	0.72	0.42–1.23	0.226
<i>Infrastructure for walking/cycling</i>						
Disagree (ref)						
Agree	0.55	0.50–1.71	0.795	0.90	0.52–1.55	0.706
<i>Aesthetics</i>						
Disagree (ref)						
Agree	1.23	0.73–2.09	0.434	1.29	0.81–2.06	0.285
<i>Safety from traffic</i>						
Disagree (ref)						
Agree	1.92	1.07–3.43	0.029	0.63	0.38–1.06	0.079
<i>Safety from crime</i>						
Disagree (ref)						
Agree	1.22	0.71–2.008	0.468	1.20	0.75–1.93	0.446

OR: odds ratios; CI: confidence interval; ^aodds ratios adjusted for age, gender, education, location, BMI, and physical activity in the table; bold *p* = significant borderline.

buffers provide high walkable environment which indirectly lowers cardiometabolic risk factors such as hypertension. Therefore, individuals living in neighborhoods with high street connectivity are more likely to meet recommended levels of walking. In addition, it has been suggested that walking “physical activity” of light-to-moderate intensity may be a particularly effective method of lowering blood pressure in older adults [35].

Perceived quality aesthetics in our study was associated with lowering hypertension. Limited literature on this relationship has found that those who perceive their aesthetics of good quality have increased their walkability and reduced hypertension risks. For example a study in Taiwan assessed aesthetics in relation to traffic noise and the risk for hypertension [36]. The authors noted that there was an increasing trend in the prevalence of hypertension for those who were exposed to road traffic noise. Similar results have been noted elsewhere [37, 38] but not for rail noise [39]. The variations in the results could be due to structural differences in the city developments, traffic density, and air pollution across the studies. However, individuals living in areas with high neighborhood aesthetics are more likely to meet recommended levels of walking [40]. In Nigeria, among young adults, seeing many people active and many interesting things to look at were significantly associated with sufficient walking [16]. Therefore, in the South African context, the population is more likely to walk in the neighborhood that is perceived to be less polluted, as compared to their counterparts in high income countries who may spend most of their time sitting in a motor vehicle each day.

It is worth noting that, in our crude logistic regression analysis, both safety from traffic and safety from crime were associated with hypertension. However, few studies have examined this relationship between crime and hypertension. For instance, in a Positive Action for Today's Health (PATH) trial ($N = 409$) among American adults, the pattern of associations showed greater neighborhood satisfaction related to attenuation of the adverse link between higher perceived neighborhood crime and higher systolic and diastolic blood pressure [41]. Other studies have linked with diastolic blood pressure in adolescents [42]. Likewise, fewer neighborhood problems [43], greater safety [44], and favorable neighborhoods [45] were associated with blood pressure. According to [44], potential hypertension-inducing features of neighborhoods included limited access to resources conducive to healthy lifestyles and an excess of neighborhood stressors. For example, in Brazil, safety was also associated with being active in leisure time [46]. Likewise, in Nigeria perceived safety from crime and safety from traffic were associated with walking [47]; thus being insecure around your neighborhood would limit your walkability which later leads to high risk of hypertension.

In our adjusted model, we noted that participants, who perceived that the proximity of services was generally more than 21 minutes from their homes, had higher odds of hypertension. Other studies have reported similar results concerning odds for hypertension with proximity to major roadway [15] and street foods [48]. One possible explanation apart from physical activity is that the availability of facilities

within walkable distance provides access, for example, to retail fruits and vegetables. The implication of the relationship suggests that participants were less likely to engage in leisure related physical activity and were more dependent on motorized transport to get to and from places. In the present study, even after we adjusted for physical activity, BMI was significantly associated (expected direction) with self-reported hypertension. Thus, overweight and obesity, independent of physical activity, may play a major role in hypertension prevalence among the participants in our study.

The study also identified lack of safety from traffic in the neighborhoods was associated with prevalent screen-detected hypertension. A previous study conducted in USA was in agreement with our study [33]. Likewise, perceived greater safety in the neighborhood was associated with a lower probability of hypertension [44]. In another meta-analysis, traffic volume on major roads within 100 m of the residence was associated with increased systolic and diastolic blood pressure [49]. In our current study, we did not find a significant relationship between physical activity and hypertension. For this reason, other factors such interactions of high volume of traffic in urban settings, gender, and age may influence hypertension. Future studies should consider investigating the mediating or moderating factors between safety from traffic and hypertension.

5. Strengths and Limitations

Our study had some limitations worth noting. Hypertension status was mostly based on self-reports which is subject to recall bias and risk of reverse causality in the sense that people's perceptions about their environment may change subsequent to hypertension diagnosis [50]. Another limitation of this study was that participation in this study was voluntary as opposed to recruitment of a more generally representative segment of the population. As a result, this study may have missed capturing information from nonparticipants with different knowledge about hypertension and its correlates [51]. This was a cross-sectional design which does not allow for causal relationships to be established. Some strengths of the current study are eminent. The study used a sample that was selected to represent urban and rural communities in South Africa. This study adds to a growing evidence base of scarce studies on the relationship between built environment and hypertension, particularly in African context.

6. Conclusion

In the current study, hypertension was highly frequent. Overall, perceived built attributes were associated with prevalent hypertension. In adjusted model, land use mix-diversity and lack of safety from traffic were significantly associated with hypertension. Furthermore, there is need to replicate similar studies using a locally developed tool in African context.

Disclosure

Opinions, findings, conclusions, and recommendations expressed are those of the authors and the funders accept no liability in this regard.

Competing Interests

The authors declare that they have no competing interests.

Authors' Contributions

Pasmore Malambo and Andre P. Kengne were involved in the conception and design. Pasmore Malambo conducted the analysis and interpretation. Pasmore Malambo and Andre P. Kengne were involved in interpretation and wrote the first draft. Pasmore Malambo, Andre P. Kengne, Estelle V. Lambert, Anniza De Villers, and Thandi Puoane were involved on drafting, revising, and final approval. Andre P. Kengne, Estelle V. Lambert, and Anniza De Villers contributed equally to this work.

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