# Perceived built environment and physical activity: relationships and consequences on prevalent cardiovascular disease and risk factors in urban and rural South Africa

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Thesis submitted in fulfilment of the requirements for the degree of

**Doctor of Philosophy**

**(Public Health)**

At the

School of Public Health

University of the Western Cape

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# Abstract

**Introduction**

Built environment (BE) attributes have been associated with a variety of health risks and outcomes, including cardiovascular disease (CVD) incidence and mortality. However, most of the existing evidence is from high-income countries which exhibit different BE attributes than those from an African context.

**Aims**

The purpose of this thesis is to assess the relationship between the BE attributes and physical activity (PA) among urban and rural adult South Africans and to examine the effect of this association, if any, on the cardiovascular disease (CVD) risk. We further investigated the associations of objectively measured BE attributes and PA and CVD risk factors in this study.

**Methodology**

This was a cross-sectional, analytical study conducted in three phases, as part of the global Prospective Urban Rural Epidemiology study (PURE) in the urban and rural sites of Cape Town and Mount Frere, South Africa. In **Phase I**, the researcher conducted a systematic review of the literature using the concept of built environment, CVD risk factors and CVDs between 2005 and April 2015. **Phase II** involved the analysis of PURE data at baseline and **Phase III** included objectively measured PA and BE attributes. The International Physical Activity Questionnaire, Neighbourhood Environment Walkability Scale, Geographic Information System and accelerometers were used for data collection. Descriptive, logistic and linear regressions were applied in the analyses.

**Results**

In **Phase I** (*study I-Chapter 2*), some of the neighbourhood environmental attributes were shown to be significantly associated with CVD risk and CVD outcomes in the expected direction. For instance, residential density, street connectivity and access to recreation facilities (high walkability), along with safety from traffic, were all associated with higher levels of PA. In addition, certain environmental attributes, such as high walkable environment, fast-food restaurants and supermarket/grocery stores were associated with low blood pressure (BP), body mass index (BMI), diabetes mellitus and the metabolic syndrome.

In **Phase II** (*study II-Chapter 3*), most participants (74%) engaged in moderate-to-high PA. In the adjusted regression models, women were 34% less likely to engage in high PA than men (OR=0.66, 95% CI: 0.47-0.95). Physical activity varied with age, marital status, education and occupation, always in differential ways between urban and rural participants (all interactions $p$ <0.047). In **Phase II** (*study IV-Chapter 4*) after adjusting for gender and age, proximity to transit stops was significantly associated with leisure-time PA (OR=4.04, 95% CI:1.21-13.48) and walking for leisure (OR=2.11, 95% CI:1.33-3.36), while the presence of sidewalks predicted the likelihood of walking for leisure (OR=1.91, 95% CI:1.11-3.29). Conversely, traffic along streets was associated with lower leisure-time PA and walking for leisure. Street lights at night increased the likelihood of walking for leisure, but the high crime rates during the day lowered leisure-time PA. Transport-related PA was independently related with distance between intersections (OR=3.78, 95% CI:1.34-10.65) and the presence of four-way intersections (OR=4.32, 95% CI:1.11-1.68). Pleasant scenery was associated with performing more transport-related PA, while crosswalks also encouraged transport-related PA (OR=3.85, 95% CI:1.51-9.81).

In adjusted logistic regression models in **Phase II** (*study V-Chapter 5*), land-use mix-diversity (OR=2.37, 95% CI:1.24-4.55) was significantly associated with self-reported hypertension. In similar multivariable models, the direction and magnitude of the effects were mostly similar for the outcomes of 'screen-detected hypertension', which was further predicted by perceived lack of safety from traffic. In study VI (Chapter 6), overweight/obesity was significantly associated with neighbourhood aesthetics (OR=0.68, 95% CI:0.50-0.93) and PA (OR=0.65, 95% CI:0.65-0.90). Aesthetics was positively associated with PA. Furthermore, both aesthetics and PA were negatively associated with overweight and obesity. However, PA did not show a significant mediating effect between aesthetics and overweight/obesity.

Finally, in **Phase III** (*study VI-Chapter 7*), access to a community centre (1000 m) was positively related to BMI (β=4.79, 95% CI:2.06 to 7.34) and diastolic BP (DBP) (β=4.97, -0.00 to 9.95; *p*=0.050) in age- and sex-adjusted models. Distance to a community centre (1600 m) was positively related to DBP (β=6.58, 1.57 to 11.58; *p*=0.010) and in the expected direction, with moderate-to-vigorous PA (β=-60.9, -134.9 to -3.7; *p*=0.039). Distance to a shopping centre (1000 m and 1600 m) were positively related to systolic BP (β=6.99, 0.03 to 13.95; *p*=0.049) and BMI (β=4.78, 1.11 to 8.45; *p*=0.011).



**Conclusions**

Altogether, some BE attributes were associated with cardiovascular risk factors. Proximity to facilities in the neighbourhood showed a positive association with cardiovascular risk factors. Females, especially in the urban area, were less likely to engage in moderate to vigorous PA and they were more likely to be overweight/obese, with high self-reported hypertension compared to their male counter parts. As a result, health policies that will encourage maintenance, access, safety, PA and usage of BE facilities are needed as an intervention strategy in lowering cardiovascular risk factors.

**Keywords**

Cardiovascular diseases, built environment, walkability, physical activity, mediation analysis, Geographic Information System, accelerometer, objective measurement, risk factors, South Africa

# Declaration

I, the undersigned, hereby declare that the work contained in this thesis is my own work, that it has not previously in its entirety, or in part, been submitted for any degree or examination in any other university, and that all the sources that I have cited or quoted have been indicated and acknowledged by means of complete references.

**PASMORE MALAMBO**

Signed……………………………………..

# Dedication

*To my parents; Moti Malambo*

*and late mother (my h.s.r.i.p); Sarah Malambo*

*To my wife; Milambo M Malambo,*

*My son Luyando Malambo*

*and*

*My daughter Matimba A Malambo*

## Acknowledgements

I am sincerely indebted for the support and assistance that made this thesis possible. Thanks to all my supervisors for their guidance throughout this process. Many thanks goes to Prof Andre P Kengne for his tirelessly mentorship on statistical skills, academic writing skills, analysis, presentations and interpretations of data. I would like also to thank Prof, Thandi for her motherly and financial support throughout the process. Many thanks go to Prof Victoria E Lambert for her material, financial and logistic support. Special thanks go to Dr Anniza De Villiers for her motherly care and support during difficult times; further, for her constant availability whenever in need of consultation and administrative issues.

I would like also gratefully acknowledge the Population Health Research Institute, Hamilton Health Sciences and McMaster University, Hamilton, Canada and the Medical Research Council of South Africa for providing access to the data used in Phase I of the study. I also would like to acknowledge the Department of Engineering and Built Environment at University of Cape Town for their assistance in computing and providing GIS data used in Phase II of the study.

I would also like to extend my appreciation to Social Innovation in Public Health Impulse fellowship program, National Research Fund through Prof Puoane, South African Medical Research Council through Prof Andre P Kengne and Dr Anniza de Villiers and the University Cape Town Sports Science through Prof Victoria E Lambert for their material and financial support during this process. Furthermore, I would like to thank Dr M Uys from the University Cape Town for her tireless engagements with the Department of Engineering and Built Environment in order to access the parcel data. In addition, I would like to appreciate Dr AR Bado for his statistical and skilful guidance during data analysis and Dr T Keswick for his generosity in editing the manuscripts.

I also extend my appreciation to Frontier Hospital Management Team for their understanding and allowing me to take study leave in the midst of shortage of staff at the hospital. Finally, I owe special thanks to all the PURE workers, especially my colleague O Kufre and Nandipha Sinyana from University Cape Town for their assistance in data collection.

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# List of abbreviations and acronyms

| | |
|---|---|
| **β** | Beta coefficient |
| **BE** | Built environment |
| **BMI** | Body mass index |
| **BP** | Blood pressure |
| **CHD** | Coronary heart disease |
| **CI** | Confidence interval |
| **CMR** | Cardio-metabolic risk |
| **CVD** | Cardiovascular disease |
| **CVDRF** | Cardiovascular disease risk factor |
| **DBP** | Diastolic blood pressure |
| **IPAQ** | International Physical Activity Questionnaire |
| **PA** | Physical activity |
| **PATH** | Positive action for today's health |
| **PHRI** | Population Health Research Institute |
| **PRISMA** | Preferred reporting items for systematic reviews and meta-analyses |
| **GIS** | Geographic information system |
| **IPEN** | International Physical activity and Environment Network |
| **Kg/m$^2$** | Kilogram per meter squared |
| **LTPA** | Leisure time physical activity |
| **M** | Meters |
| **MET** | Metabolic equivalent |
| **MET min/week** | Metabolic equivalents per minute per week |
| **Min** | Minutes |
| **NCD** | Non-communicable diseases |
| **NEWS** | Neighborhood Environment Walkability Scale |
| **MVPA** | Moderate to vigorous physical activity |
| **OR** | Odds ratios |
| **PURE** | Prospective urban rural epidemiology |
| **Ref** | Reference |
| **SA** | South Africa |
| **SBP** | Systolic blood pressure |
| **SD** | Standard deviations |
| **SPSS** | Statistical package for the social sciences |
| **SSA** | Sub-Saharan Africa |
| **STROBE** | Strengthening the reporting of observational studies in epidemiology |
| **TPA** | Total physical activity |
| **TRPA** | Transport-related physical activity |
| **UK** | United Kingdom |
| **USA** | United States of America |
| **UWC** | University of the Western Cape |
| **WL** | Walking for leisure |
| **WC** | Waist circumference |
| **WHO** | World Health Organization |
| **WHR** | Waist-hip ratio |

# Glossary and definitions

| | |
|---|---|
| **Accelerometer** | A monitoring device that measures the intensity of an activity |
| **Adult** | An individual aged 18 years and older |
| **Body mass index** | One of the most commonly used measures for defining overweight and obesity, calculated as weight in kilogram (kg) divided by the square of height in meter (m) |
| **Built environment** | Defined broadly to include land use patterns, the transportation system, and design features that together provide opportunities for travel and physical activity. *Land use patterns* refer to the spatial distribution of human activities. The *transportation system* refers to the physical infrastructure and services that provide the spatial links or connectivity among activities. *Design* refers to the aesthetic, physical, and functional qualities of the built environment, such as the design of buildings and streetscapes, and relates to both land use patterns and the transportation system. |
| **Cardiovascular disease** | A general term that describes a disease of the heart or blood vessels. Blood flow to the heart, brain or body can be reduced as the result of a blood clot (thrombosis), or by a build-up of fatty deposits inside an artery that cause the artery to harden and narrow (atherosclerosis) |
| **Confidence interval** | The computed interval with a given probability e.g. 95%, that the true value of a variable such as a mean proportion, or rate is contained within the interval |
| **Cross-sectional study** | A study that examines the relationship between disease (or other health-related characteristics) and other variables of interest as they exist in a defined population at one particular time |
| **Ecological models** | Based on social cognitive theory, which explains behaviour in terms of reciprocal relationships among the characteristics of a person, the person's behaviour, and the environment in which the behaviour is performed. Ecological models emphasize the role of the physical as well as the social environment |

| | |
|---|---|
| **Epidemiology** | The study of the distribution and determinants of health-related states and events in specified populations and the application of this study to the control of health problems |
| **Gender** | The socially constructed roles, behaviours activities, and attributes that a given society considers appropriate for men and women |
| **Geographic information system** | An automated system for the capture, storage, retrieval, analysis, and display of spatial data |
| **Hypertension** | Having a blood pressure reading greater than 140/90 mmHg |
| **Mediating model** | A model seeks to identify and explain the mechanism or process that underlies an observed relationship between an independent variable and a dependent variable via the inclusion of a third hypothetical variable, known as a mediator variable |
| **Metabolic equivalent (MET)** | A unit used to estimate the metabolic cost (oxygen consumption) of physical activity. Activities that raise the rate of energy expenditure are frequently expressed as the ratio of working to resting metabolic rate. |
| **Neighbourhood** | A geographically localised community within a larger city, town, suburb or rural area |
| **Non-communicable diseases** | A medical condition or disease that is non-infectious or non-transmissible |
| **Obesity** | A condition where a person has accumulated so much body fat that it might have a negative effect on their health |
| **Obesity and overweight** | Adults are defined as being obese if they have a body mass index (BMI) of 30 kg/m$^2$ or greater, and as being overweight if they have a BMI of 25 but less than 30 kg/m$^2$ |
| **Odds** | The probability that a particular event will occur divided by the probability that the event will not occur |
| **Odds ratios** | The odds of a particular exposure among persons with a specific disease divided by the corresponding odds of exposure among persons without the disease |
| **Overweight** | Having more body fat than is optimally healthy |

| | |
|---|---|
| **Physical activity** | Physical activity is any body movement that works your muscles and requires more energy than resting and makes your heart beat faster. Walking, running, dancing, swimming, yoga, and gardening are a few examples of physical activity |
| **Prevalence** | The number of a given disease or other conditions in a given population at a designated time |
| **Prospective cohort study** | A longitudinal cohort study that follows over time a group of similar individuals (cohorts) who differ with respect to certain factors under study, to determine how these factors affect rates of a certain outcome |
| **Public Health** | The art and science of preventing disease, promoting health and extending life through organised efforts of society |
| **Reliability** | Precision or degree to which an instrument or scale result is reproducible |
| **Risk factors** | A factor that raises the probability of an adverse event/outcome occurring |
| **Rural** | Suggests an area with a distinctive pastoral landscape, unique demographic structure (relatively more elderly people and children) and settlement patterns, isolated with low population density, mostly extractive economic activities and a distinct socio-cultural milieu characterised by, for example, African traditional leaderships systems |
| **Sex** | The biological and psychological characteristics that define men and women |
| **Systematic review** | A type of literature review that collects and critically analyses multiple research studies or papers |
| **Urban** | An area with a large amount of people residing in it, an area that has been significantly developed, or an area where the distance between buildings is very small |
| **Validity** | The degree of accuracy to which a research study measures what it intends to measure |
| **Walkability** | A measure of how friendly an area is for walking |
| **ZAR** | South African Rand |

## A preference

*This thesis is written in article format and the contributions of the student during this process are outlined below.*

***The role of a PhD student in the study***

The roles of the student in the study are explained in the steps that were undertaken during the process as follows:

***Step I***

During the process of this study, the student designed, developed, and wrote the study proposal.

***Step II***

This was ***Phase I*** of the study which involved a systematic literature review. The student designed, developed, and conducted a review of the literature, analysed the data, interpreted the results and wrote **Chapter 2**.

***Step III***

This was ***Phase II*** of the study which involved secondary data analysis from the Prospective Urban Rural Epidemiology (PURE) study. At this stage of the study, the student obtained merged data sets and cleaned the data. The student further designed, developed, analysed, interpreted and wrote all the chapters from 3 to 6 that forms part of this thesis.

***Step III***

This was ***Phase III*** of the study. During this Phase, objective assessment of built environment attributes and physical activity were conducted in Langa Township in Cape Town. The geographic information system (GIS) was used to assess the built environment attributes and accelerometers were used to measure physical activity. The role of the student in this Phase included training field workers on the applications and use of accelerometers; geocoding of participants' household addresses; data collection, entry, merging, cleaning, analysis, and interpretation; and writing up **Chapter 7** of the study.

In all these steps of the study, the student received academic, financial, socio- and moral support from his four supervisors.

## Publications and presentations

*The following original papers and presentations have arisen from work reported in this thesis.*

*Papers are presented as chapters (2-7).*

1. Pasmore Malambo. Relationship between perceived physical activity levels and cardiovascular risk factors in urban and rural communities of South Africa: the PURE study. *Journal Club,* University of the Western Cape, 3rd March, 2014

2. Pasmore Malambo. Prevalence and socio-demographic determinants of physical activity levels among South African adults in urban and rural communities. *PhD workshop*, University of the Western Cape, 30th June, 2014

3. Malambo P, Kengne AP, De Villiers A, Lambert EV, Puoane T (2016) Built Environment, Selected Risk Factors and Major Cardiovascular Disease Outcomes: A Systematic Review. Plos One 11(11): e0166846. doi: 10.1371/journal.pone.0166846. *(Chapter 2).*

4. Malambo et al. Prevalence and socio-demographic correlates of physical activity levels among South African adults in urban and rural communities. *Archives of Public Health* (2016) 74:54. doi: 10.1186/s13690-016-0167-3. *(Chapter 3).*

5. Malambo et al. Association between perceived built environmental attributes and physical activity among adults in South Africa. *BMC Public Health* (2017) 17:213. doi 10.1186/s12889-017-4128-8. *(Chapter 4).*

6. Pasmore Malambo, Andre P Kengne, Estelle V. Lambert, Anniza de Villiers, and Thandi Puoane**.** Association between perceived built environment and prevalent hypertension among South African adults. *Advances in Epidemiology*.2016. doi.org/10.1155/2016/1038715. *(Chapter 5).*

7. Pasmore Malambo, Andre P Kengne, Anniza de Villiers, Estelle V Lambert, Thandi Puoane. Does physical activity mediate the association between perceived neighbourhood aesthetics and overweight/obesity among South African adults living in selected urban and rural communities? *(Completed Manuscript accepted for publication in Journal of Physical Activity and Health; Chapter 6).*

8. Pasmore Malambo, Andre P Kengne, Anniza de Villiers, Estelle V Lambert, Thandi Puoane. The relationship between objectively-measured attributes of the built environment with selected cardiovascular risk factors in a South African urban setting. *(Completed Manuscript; Chapter 7).*

**Appendices:**

# Chapter 1

# General Introduction

## 1.1 Background information of the study

Non-communicable diseases (NCD) such as diabetes, cardiovascular disease and cancers are a major cause of morbidity and mortality worldwide, and disproportionately affect developing countries [1]. These diseases are predicted to account for seven out of every ten deaths in developing countries by 2020 [2]. The morbidity from NCD is exacerbated by the prevalence of contributing factors such as high blood pressure (BP), high cholesterol, tobacco use, excessive alcohol use, inadequate intake of fruit and vegetables, and being overweight, obese or physically inactive. In South Africa, more than 60% of the population has migrated from rural to urban centres [3], where they have become increasingly exposed to a more sedentary lifestyle, with greater access to highly-processed food of poor nutritional quality, without necessarily improving their socio-economic status [4]. Thus, sedentary behaviour prevails and people are overweight or obese, with over 50% of women and more than 20% of men having a body mass index (BMI) in excess of 25 $kg/m^2$ [2,5]. In 2012, NCDs accounted for 43.4% of total mortality and, ischaemic heart disease and strokes were the second and fourth leading causes of death in South Africa, resulting in the loss of nearly 65 000 lives [6,7].

Nevertheless, it has been suggested that chronic NCD and the associated modifiable risk factors can be prevented through policy development, environmental and social change, supportive infrastructures and initiatives implemented in community settings [8]. However, these strategies have received little attention in Africa.

One of the modifiable health risk targets of these strategies and interventions is physical activity (PA), described as bodily movement produced by skeletal muscles resulting in increased caloric expenditure above the basal metabolic rate [9]. The link between PA and reduced risk of cardiovascular and all-cause mortality has been firmly established, in low-, middle- and high-income countries [10-13]. The mitigating effect of PA on cardiovascular mortality is through its ability to reduce CVD risk factors such as obesity and BP, and to improve glucose tolerance and lipid profile [14]. In spite of these recognised benefits, millions of people are inactive and their number is increasing. In South Africa, 45% of adults have been reported to be inactive [15].

Furthermore, PA is a complex behaviour which can be described in different contexts (domains). For example, PA can be transport-related, work-related, household-related or may include leisure-time pursuits, all of which benefit health. Leisure-time PA refers to discretionary or volitional PA, pursued as purposeful exercise targeting health, fitness or quality of life, or participation in sport or PA, simply for enjoyment or recreation. Alternatively, utilitarian PA can occur in the occupational domain, as work which requires sustained physical exertion, or in household-related activities, such as housecleaning, and maintaining a garden, or washing clothes by hand, or carrying water. Active transportation refers to walking or cycling to get and from places, such as commuting for work or school. Participation in different physical activities is considered to be influenced by a complex interaction of socio-demographic, physical, psycho-social and socio-cultural, socio-political and environmental factors [16].

In recent research, the various PA domains have been linked with characteristics of the built environment (BE) where people live [17]. Built environments are generally defined as a "totality of places built or designed by humans, including buildings, grounds around buildings, layout of communities, transportation infrastructure, parks and trails" and these can either positively or negatively influence health behaviours [18]. Research into the association of built environment factors with levels of PA is growing [19]. In fact, environmental attributes such as land use, proximity to recreational facilities, presence of sidewalks, and neighbourhood aesthetics to recreational PA and walking have been linked in many studies [20]. Furthermore, particularly for older adults, convenient access to non-residential destinations, low levels of crime and neighbourhood satisfaction may all stimulate PA [21].

Despite the above findings, study results have been inconsistent. For example, while in some studies increased levels of PA have been found among individuals living in areas that have a high residential density, land-use mix, and street connectivity [20] in other studies this was not observed [22]. Studies with inconsistent results largely appear to have relied on subjective measures of BE and PA, which have limitations when compared objective measures derived from a geographic information system (GIS) and accelerometers [23]. Modern GIS and accelerometers have become more sophisticated, and allow assessments of specific behaviours such as walking and cycling for recreational and transportation purposes. These measurement advances have allowed recent research to examine multiple elements of the environment associated with the different domains of PA [24]. For example, in one study, several associations between objective measures of traffic volume, traffic speed, and crashes with leisure, walking, and transportation activity were found [25]. These researchers proposed that evaluating objective and subjective measures of the BE and PA might be necessary to effectively interpret the relationship and recommended appropriate interventions [25].



Studies concerning the association of PA with BE are also geographically limited, most having been conducted in developed countries [26], with limited systematic ecological analyses available for South Africa and Africa at large. For example, Sallis *et al.*, [17] assessed the influence of perceived environmental attributes on PA among urban dwellers in 11 developed countries. Built environment attributes also vary widely between urban and rural areas [27]. Currently, very little is known about perceived environmental attributes and PA in rural areas [26]. Urban environmental attributes linked to PA, such as sidewalks, street connectivity, population density and diversity of land use, may not be applicable in a rural setting [28]. Wilcox *et al*., [29] in their study, found that rural women were less likely to mention sidewalks, streetlights, high crime, access to facilities, and frequently seeing others exercise in their neighbourhood than their urban counterparts. Furthermore, rural areas have a low population density and residents live further away from activity areas than do those in urban areas. Consequently, generally defining rural areas as "all areas outside urban areas" [27] is misleading, because the environmental characteristics relevant to PA may vary according to climate, landscape, built form, and cultural traditions [30].

Both the structure of built environments and how they are perceived may differ among communities in South Africans, sub-Saharan Africa (SSA), and the developed world. For example, the concept of "walkable" neighbourhoods in Western communities describes cities and neighbourhoods that were designed for transportation such as walking and cycling, but these may differ from SSA communities. In developed countries, built environments with supportive features are related to PA [17], but this is not necessarily a global phenomenon. Studies on the influence of the BE on PA in Africa are limited [30], and it is not known if findings from comparable studies in developed countries are applicable in a local African context. Thus, researchers in Africa have begun to evaluate BE measures that may be effective in a regional context [31]. The International Physical activity and Environment Network (IPEN) focuses on all aspects of built environments on a global scale, including a psychometric evaluation of the Neighborhood Environment Walkability Scale (NEWS) in SSA countries, with cross-national comparisons of findings on environmental correlates of PA. A major aim of research in this field is to establish measures of internationally comparable environmental variables and those of particular relevance to the local Africa environment [32]. In this context, NEWS-Africa has been developed to measure BE conditions for planning purposes, and to evaluate PA and policy interventions in Africa [33].

Besides built environments, personal, family, social and economic factors may influence PA. In support of this idea, research has highlighted that neighbourhood safety, an important aspect of the neighbourhood social environment, and socio-economic factors potentially influence PA behaviour [34]. Neighbourhoods perceived to be unsafe at night have been shown to act as a barrier to regular PA among individuals, especially women, living in urban low-income housing [35].

Furthermore, research surrounding attributes of the BE and CVD risk factors is limited, but it has been shown that persons living in areas with better land-use mix tend to have a lower probability of having hypertension [36] and coronary heart disease (CHD) risk [37]. Conversely, persons living in sprawling areas, described as car-dependent environments are likely to have a higher prevalence of hypertension and obesity [38].

Although the literature differentiates among the risk factors associated with CVD, the influence of perceived BE and PA on CVD risk factors is less understood [39].

## 1.2 Study setting

### 1.2.1 Langa Township - Western Cape

Langa Township is one of the oldest suburbs in City of Cape Town Municipality in the Western Cape Province, South Africa, and was a township that resisted apartheid (http://www.sahistory.org.za/place/langa-township). Langa was established in 1927 in terms of the 1923 Urban Areas Act (http://www.sahistory.org.za/place/langa-township), and is one of many areas in South Africa that was designated for black Africans prior to the apartheid era. Langa Township is located in the Cape Flats, 11 km south-east of the centre of Cape Town (see Figure 1.1) in the Western Cape Province. In 2011, this Township enclosed 3.09 $km^2$ of the total land area, with an estimated population density of 17,000/$km^2$ [40]. According to Statistics South Africa [40], the population in the Township in 2011 was predominantly black African (99.1%) and there were more women (50.1%) than men (49.0%). Census data further revealed that 40% of those age 20 years and older had completed Grade 12 or a higher qualification, whereas 60% of the labour force among those aged 15–64 years was employed. On the other hand, 72% of households had a monthly income of R3 200 or less and 58% lived in formal dwellings [40].

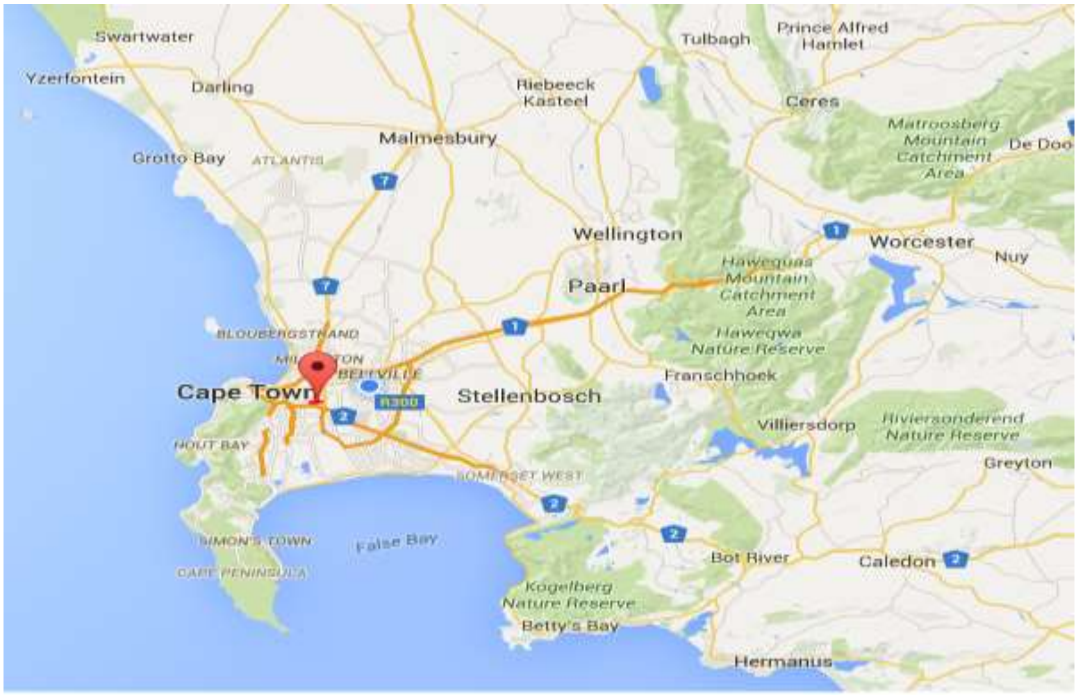



**Figure 1.1** Map of the Western Cape Province showing Langa Township



### 1.2.2 Mount Frere - Eastern Cape Province

Mount Frere falls within Umzimvubu Local Municipality, which is an administrative area in the Alfred Nzo District in the north-western corner of the Eastern Cape Province. Elundini Municipality to the West, Greater Kokstad Municipality and Matatiele Municipality to the North, Mhlontlo Municipality to the South, and Ntabankulu Municipality to the East borders Mount Frere. The Umzimvubu Local Municipality covers an area of 2,506 km$^2$ (http://www.localgovernment.co.za). In Figure 1.2 the position of Mount Frere in the Umzimvubu Local Municipality is shown.

Mount Frere covers an area of 3.53 km$^2$. The population was reported to be 5,252 in 2011 [40]. The population density was generally low with an average population density of 1,486 per km$^2$. The population was documented to be predominantly female (54.78%) and African (96.08%).

The population was mostly young and below the age of 35 years, 23.3% were still dependent (1–14 years), 75.1% are potentially economically active (15–65 years) and 1.6% are elderly (65+years) [40]. The people from this area were reported to have low education levels with 0.8% who had no schooling while 26% only had some form of higher education. Only 38.2% of the population had completed Grade 12.

Poverty levels are high with 80.1% of the population earning less than R800 per month and technically living below the poverty line. This is compounded by high levels of unemployment (municipal prevalence of unemployment is 78.2%, which is higher than the district level). High poverty levels imply a high dependency on social grants. Overall, 58.1% households are headed by females [Umzimvubu Local Municipality Integrated Development Plan].


**Figure 1.2** Position of Mount Frere in Umzivubu Local Municipality



## 1.3 Rationale of the study

There is growing evidence that the BE influences walking-based PA levels [41]. Therefore, it is advised that changing the BE design, potentially increases total PA levels, whereby CVD risk decreases [42, 43]. Specifically, in one study using objective measures of BE and PA, it was shown that individuals living in high-walkability neighbourhoods accumulate 5.8 more minutes of moderate-to-vigorous PA per day compared to low-walkability neighbourhoods [17]. This extra time is meaningful based on evidence showing a dose-response relationship between PA and the incidence of several chronic diseases such as CVD. Thus, given the evidence that the BE may influence PA prevalence, and consequently disease risk, a local exploration of the relationship of variations in the perceived and objectively measured BE and CVD risk factors, is warranted.

Additionally, despite the need to understand the relationship between the BE and health, previous studies have strived to establish a causal relationship between the BE and PA [44]. Physical activity and CVD risk factors are well-recognised to be causally linked, whereby increased PA is associated with decreased CVD risk [45]. If CVD risk were to vary predictably between residents of neighbourhoods of varying PA design, then it would provide implied evidence of a relationship between the BE and total PA [46]. Thus far, this has not been investigated in a South African context. Hence, the incentive for conducting studies in South African urban-rural areas so as to understand how the BE characteristics affect PA behaviour among adults and its consequential effects on CVD risk factors and prevalent CVD.

## 1.4 Aim of the study

In this study, the aim was to assess the relationship between the perceived BE characteristics and PA among urban and rural adults of PURE-UWC areas in South Africa, and to examine the effect of this association, if any, on the cardiovascular risk factors. We further attempted to investigate the associations between objectively measured BE attributes and selected CVD risk factors.



## 1.5 Objectives of the study

***Phase I: Systematic literature review***

**1.5.1** To conduct a systematic review of literature to examine the influence of built environmental attributes on CVD risks and major CVD outcomes (**Chapter 2-study I**).

*Phase II: Analysis of PURE cohort at baseline*

**1.5.2** To determine the prevalence and socio-demographic factors associated with PA among South African adults in urban and rural communities (**Chapter 3-study II).**

**1.5.3** To investigate the association between perceived environmental attributes and leisure-time and transport-related PA (**Chapter 4-study III**).

**1.5.4** To investigate the association between the perceived BE and prevalent hypertension among adult South Africans (**Chapter 5-study IV**).

**1.5.5** To determine the extent to which PA mediates the association between perceived neighbourhood aesthetics and overweight/obesity among South African adults living in selected urban and rural communities (**Chapter 6-study V**).

*Phase III: Objective assessment of the built environment attributes for CVD risk factors*

**1.5.6** To investigate the relationship between objectively-measured attributes of BE and selected cardiovascular risk factors in a South African urban setting (**Chapter 7-study VI**).



## 1.6 Theoretical framework of the study

For the current study, the ecological models on the built environmental influence of individuals' PA and health were applied [47] (Figure 1.3). In this model, an individual's behaviour is claimed to be influenced by multiple factors, viz. at an individual, community, BE and policy level, which may interact, and thereby impact on health status [47]. Researchers have found that, for example lower age, sex [48] and high self-efficacy are individual factors that are positively correlated with PA [49]. Social support and seeing others being physically active are factors related to the social environments that correlated with PA [50].

Ball et al. [51] demonstrated that some characteristics of built environments may facilitate or hinder PA. For example, aesthetics and availability of recreational facilities have positive associations with PA [51]. The BE has been related to the prevalence of CVD and risk factors such as obesity and hypertension [5], while PA is believed to be a critical mechanism, which may reduce the CVD prevalence if BEs are modified [53].

The policy domain refers to legislation or policy-making actions that have the potential to affect PA levels in the population [54]. This could include, for example, policies to increase the use of PA on prescription within the health-care system, workplace policies or city planning policies aimed at creating environments that promote PA, such as traffic calming, car-free zones, or walking paths and cycling trails.

The study of environmental factors in PA is consistent with an ecological approach to the study of health behaviour. Sallis and Owen [55] noted that ecological models are multilevel and typically focus on environmental causes and interventions. Therefore, specific ecological models may be needed for specific types of activity because different activities occur in different settings. Thus, a key rule is that interventions should be most effective when they change the person, the social environment, and built environments and policies within the neighbourhoods where people live.

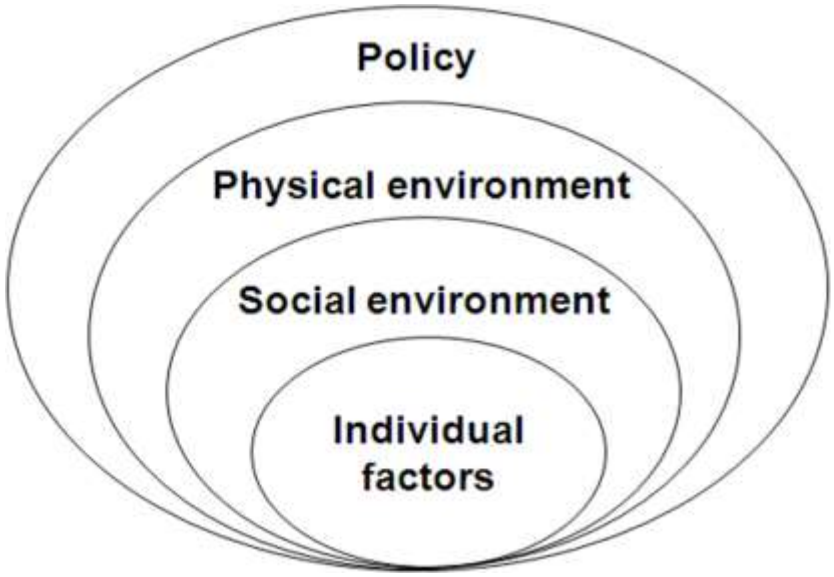



**Figure 1.3** An ecological model of 4 domains of active living
**Source:** Adapted from Sallis et al. [47]



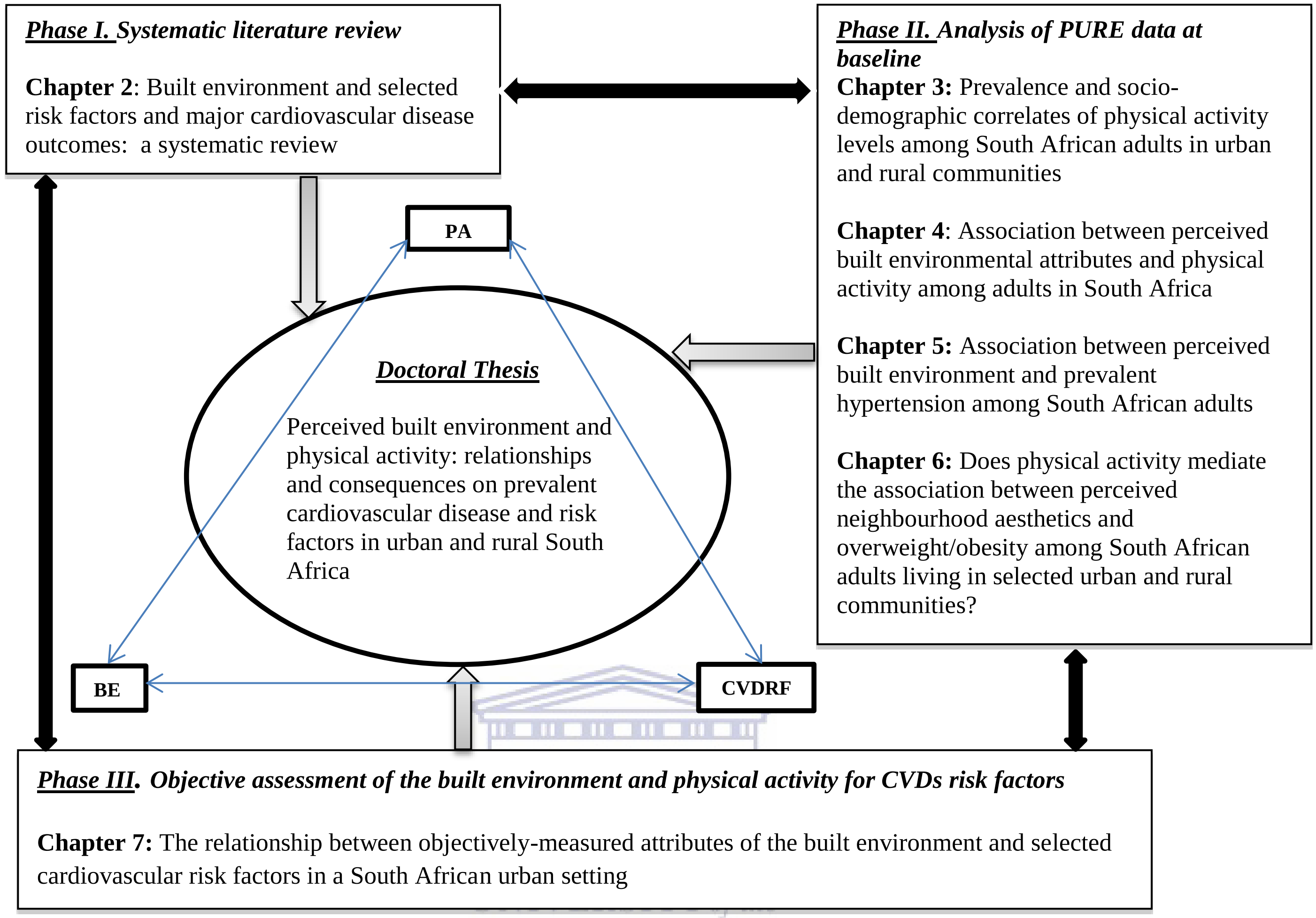
## 1.7 Overview of methodology

In this Chapter, the method utilised in the respective studies that were conducted is explored. Broad descriptions of the research settings utilised in the study are also provided in the background information. However, in each study, a brief description of the setting is outlined. The population and sampling methods used in each study is also specified in this Chapter. In addition, the study design and methods of data collection are noted for each study.

The study instruments used for data collection at baseline were: the adult questionnaire for socio-demographic characteristics, International Physical Activity Questionnaire (IPAQ) to measure PA domains and the NEWS to measure perceived BE attributes. In Phase III, the GIS was used to objectively measure BE attributes, and accelerometers were used to objectively measure PA levels (intensity and duration). In each study, a detailed description of the data analysis is outlined. Finally, the issues of ethical considerations regarding the study are also reported.

## 1.8 Chapter descriptions

To understand the relationship between BE, PA and the prevalent CVD and risk factors in Langa and Mount Frere, the overall study and the different phases are outlined in this Section. A brief description of the methodology and phases are defined outlined below as follows: ***Phase I:*** This was a systematic literature review reported in **Chapter 2**. ***Phase II:*** This phase comprised a secondary data analysis for both communities as described in **Chapters 3 to 6**. ***Phase III*** involved an objective assessment of BE and CVD risk factors, which is reported in **Chapter 7**. The schematic representation of the study for the different phases is illustrated in Figure 1.4. Finally, the summary, conclusions and recommendations of the study are highlighted in **Chapter 8**. A brief presentation of the scope of each chapter is outlined below.




PURE, prospective urban rural epidemiology; PA, physical activity; BE, built environment; CVDRF; cardiovascular disease risk factors: CVD. cardiovascular diseases

**Figure 1.4** Schematic representation of the study

## *General description of chapters*

### *Chapter 1: General introduction*

This Chapter forms the backbone of the current study and provides an overview of the aim and scope of the research project described in this thesis. Various BE attributes that are associated with CVD risk factors and other major CVD outcomes are highlighted and further detail of both communities where the current study was conducted is described. Furthermore, the rationale, aims and objectives of the main study is outlined in this Chapter. Finally, the framework which underpins the link between the theoretical and BE attributes that form an inquiry into its relationship and consequences on CVD and its risk factors among adult South Africans is described.

***Chapter 2: Built environment, physical activity and selected risk factors and major cardiovascular disease outcomes: a systematic literature review***

To understand the relationships and potential consequences of the BE and PA on CVD prevalence and risk factors, a comprehensive systematic review of available literature was conducted (**Chapter 2**). The work reported in this Chapter covered studies published from 2005 to April 2015 identified via a thorough search of English language literature across multiple databases and using an appropriate combination of search terms. The review assessed the methodological quality of each article identified using the 'Strengthening the Reporting of Observational studies in Epidemiology' (STROBE) and the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. This review enabled us to produce 40 articles of which 18 were significantly eligible for analysis. According to this review there is still a lack of studies on the BE and PA with its relationship and consequences on CVD prevalence and risk factors in the African context.

In the current review, various BE attributes that are linked with CVD risk factors and selected major CVD outcomes are discussed, and prevention programmes, in conclusion, should account for neighbourhood environmental attributes in the communities where people live. Additionally, in future studies, the associations of CVD risk and outcomes with a broad set of neighbourhood attributes using a longitudinal approach to better understand the direction of effects should be explored.

***Chapter 3: Prevalence and socio-demographic correlates of physical activity levels among South African adults in urban and rural communities***

This was a cross-sectional study using secondary data from the Cape Town (urban) and Mount-Frere (rural) sites of the PURE study conducted in 2009. The study involved a randomly selected sample of males and females, aged 35 years and older. The findings of the study highlight that most of the participants engaged in moderate to vigorous PA, however, women were less likely to engage in vigorous PA compared to men. The relationship between PA and socio-demographic factors varied across settings. For example, those with secondary education in urban areas were more likely to engage in moderate PA and persons who were not married were more likely to engage in moderate and vigorous PA.

***Chapter 4: Association between perceived built environmental attributes and physical activity among adults in South Africa***



The association between perceived environmental attributes and leisure-time and transport-related PA is investigated in this Chapter. These outcome variables were used as they have shown to be associated with different perceived BE attributes in other countries and settings. In the study, it was noted that variable perceived BE attributes were associated with leisure, walking and transport-related PA. The need for policy strategies aimed at improving or maintaining these perceived environmental attributes to promote PA were observed in this study.

***Chapter 5: Association between perceived built environment and prevalent hypertension among South African adults***

Very little is known about the association between perceived built environmental attributes and hypertension among adults in the African context. Using the PURE data this association was potentially investigated in adult South Africans. In an adjusted model, land-use mix-diversity was significantly associated with self-reported hypertension. In similar multivariable models, the direction and magnitude of the effects was mostly similar for the outcomes of 'screen-detected hypertension' which was further predicted by perceived lack of safety from traffic. In summary, these results highlight that an ecological approach, and recognition of environmental and social determinants of proximal health outcomes will be necessary to prevent and control hypertension among African communities.

***Chapter 6: Does physical activity mediate the association between perceived neighbourhood aesthetics and overweight/obesity among South African adults living in selected urban and rural communities?***

We aimed to investigate the mediation effects of PA between the perceived neighbourhood aesthetic environment and overweight/obesity in free-living South Africans. The methodical aspect has already been mentioned above. In this current study, no evidence was found in the mediating model to support a significant effect that PA had on the relationship between aesthetics and overweight/obesity. In conclusion, it was noted that the use of longitudinal studies to evaluate food-related environments may assist to unpack other factors that are associated with overweight or obesity in these research settings.

***Chapter 7: The relationship between objectively-measured attributes of the built environment with selected cardiovascular risk factors in a South African urban setting***

There is a scarcity of data on the relationship of objectively-measured BE walkability with cardio-metabolic risk of populations in developing countries. Thus, in this study, the association among objectively-measured BE walkability with BMI, BP and PA in adult South Africans was assessed. This study was nested within the PURE cohort study. This was a cross-sectional in nature utilising convenient sampling technique for those who were interested to participate in the study. The study procedures were divided into two sections; the first section involved data collection using accelerometers to measure PA. The second involved geocoding of participants' addresses. These codes were later used to measure proximity of selected BE attributes to the participants' households using GIS. The observation made in this study, was that community centres and shopping malls were associated with selected CVD risk factors.

***Chapter 8: Summary, implications on public health and recommendations***

In this Chapter, a final summary of the findings of the dissertation are reported and integrated. Conclusions are outlined on: prevalence and socio-demographic correlates of PA; the association between perceived built environmental attributes and PA; association between perceived BE and prevalent hypertension; the mediating effect of PA on association between perceived neighbourhood aesthetics and overweight/obesity, and the relationship of objectively measured BE walkability and selected cardiovascular risk factors.

Policy and strategy recommendations arising from these studies are incorporated in the discussion, along with recommendations for future research. Finally, some limitations of the various studies conducted are also highlighted, which inspire recommendations for research, policies and interventions at community levels.

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# Chapter 2

## Built environment, selected risk factors and major cardiovascular disease outcomes: a systematic review

Pasmore Malambo, Andre Pascal Kengne, Anniza De Villers, Estelle V Lambert, Thandi Puoane.

## Abstract

**Introduction:** Built environment attributes have been linked to cardiovascular disease (CVD) risk. Therefore, identifying built environment attributes that are associated with CVD risk is relevant for facilitating effective public health interventions.

**Objective:** To conduct a systematic review of literature to examine the influence of built environmental attributes on CVD risks.

**Data source:** Multiple database searches including Science direct, CINAHL, Masterfile Premier, EBSCO and manual scan of reference lists were conducted.

**Inclusion criteria:** Studies published in English between 2005 and April 2015 were included if they assessed one or more of the neighbourhood environmental attributes in relation with any major CVD outcomes and selected risk factors among adults.

**Data extraction:** Author(s), country/city, sex, age, sample size, study design, tool used to measure neighbourhood environment, exposure and outcome assessments and associations were extracted from eligible studies.

**Results**: Eighteen studies met the inclusion criteria. Most studies used both cross-sectional design and Geographic Information System (GIS) to assess the neighbourhood environmental attributes. Neighbourhood environmental attributes were significantly associated with CVD risk and CVD outcomes in the expected direction. Residential density, safety from traffic, recreation facilities, street connectivity and high walkable environment were associated with physical activity. High walkable environment, fast food restaurants, supermarket/grocery stores were associated with blood pressure, body mass index, diabetes mellitus and metabolic syndrome. High density traffic, road proximity and fast food restaurants were associated with CVDs outcomes.

**Conclusion:** This study confirms the relationship between neighbourhood environment attributes and CVDs and risk factors. Prevention programs should account for neighbourhood environmental attributes in the communities where people live.

## 2.1 Introduction

Current global mortality rates from non-communicable diseases (NCDs) remain unacceptably high and are increasing [1]. More than 70% of global cardiovascular disease (CVD), are attributable to modifiable risk factors [2]. Rapidly globalization is accompanied by increasing urbanization, population growth and changes in demographics and promotes trends towards unhealthy lifestyles [3]. The ecological model, however, states that an individual's behaviour is influenced by multiple level factors such as social, neighbourhood environment, and policy factors [4,5]. One of these factors, the neighbourhood environment, and its link to health have been the focus of an increasing number of studies in recent years [6]. These studies are from a variety of disciplines, including urban planning and transportation planning [7].

Despite increases in the number of studies on the relationship between the neighbourhood environment and health, the potential impact of the neighbourhood environment across a range of health outcomes has not been fully explored. For instance, existing studies have focused on specific CVD risk factors such as obesity [7–9], metabolic syndrome [10], physical activity [11,12] and walking [13]. A recent review on the subject matter was restricted to obesity and related risk factors [14]. While such a review is necessary to guide future research and policy formulation in this sector [15], there is paucity of studies that have broadly reviewed the relationship of neighbourhood environment with major CVD outcomes and risk factors. Therefore, the purpose of this study is to synthesize the studies on the association between a number of neighbourhood environment attributes and CVD risks.

## 2.2 Methodology

### 2.2.1 Data Sources/ Search strategy

A comprehensive search was conducted to identify all research articles published from 2005 to 2015 that examine neighbourhood environment, major CVD outcomes and selected risk factors (Table 2.1). English language articles were identified from the following databases: EBSCO (including: Academic Search, CINAHL, Global Health, Health Source: Nursing/academic and Medline) and Science Direct. Significant studies were identified using any of the following keywords: neighbourhood environment, perceived neighbourhood environment, perceived built environment, land use mix diversity, physical activity, social environment, overweight or obesity, hypertension, diabetes mellitus, metabolic syndrome, coronary heart disease and myocardial infarction.

**Table 2.1 Database search strategies**

| No | Search terms |
|---|---|
| **CINAHL** | |
| **No** | **Search terms** |
| 01 | Neighbourhood environment |
| 02 | Physical activity |
| 03 | Adults |
| 04 | #1 and #2 and #3 |
| **Master File Premier** | |
| 01 | Built environment |
| 02 | Overweight or obesity |
| 03 | Adults |
| 04 | #1 and #2 and #3 |
| **Science Direct** | |
| 01 | Perceived built environment |
| 02 | Diabetes mellitus |
| 03 | Adults |
| 04 | #1 and #2 and #3 |
| **EBSCO host** (including; academic search complete, CINAHL, Global health, Health source: nursing/academic, Medline) | |
| 01 | Perceived neighbourhood environment |
| 02 | Hypertension |
| 03 | Adult |
| 04 | #1 and #2 and #3 |
| 05 | Perceived built environment |
| 06 | Diabetes mellitus |
| 07 | Adults |
| 08 | #5 and #6 and #7 |
| 09 | Land use mix diversity |
| 10 | Metabolic syndrome |
| 11 | Adults |
| 12 | #9 and #10 and #11 |
| 13 | Social environment |
| 14 | Myocardial infarction |
| 15 | Adults |
| 16 | #13 and #14 and #15 |
| 17 | Perceived neighbourhood environment |
| 18 | Coronary heart disease |
| 19 | Adults |
| 20 | #17 and #18 and #adults |

### 2.2.2 Study selection

Titles and abstracts of all identified articles were assessed for their potential eligibility. Full texts of potentially eligible articles were then retrieved and their eligibility was verified against the study eligibility criteria. Fig 2.1 (see appendix) represents the flow of the literature review conducted according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines [16], Table 2.2 (see appendix). Studies published in English were included if: 1) they used a Geographic Information System (GIS) [17] or subjectively assessed one or more of the built environment factors categorized according to the validated and reliably tested 'Neighborhood Environment Walkability Scale' (NEWS) which is a better questionnaire to assess the local environment [18]; 2) examined the relationship with any of the major CVD outcomes including myocardial infarction, coronary heart disease and stroke; 3) examined selected risk factors including physical activity (categorized in domains were considered), overweight or obesity, hypertension and diabetes mellitus; 4) were original reports on studies conducted among subjects aged 18 years and above; and 5) if the purpose of the studies was to explore the association between the variables of interest using multivariate analysis. Exclusion criteria were as follows: 1) Studies exclusively conducted on adolescents; 2) studies that employed a qualitative design; 3) systematic review papers; 4) publications from studies where subjects had difficulty with walking and 5) studies that did not meet the criteria for current review.

### 2.2.3 Data extraction

The information extracted included the first authors' name, publication year, the sample size, gender, age range of the subjects, country and city where the study was conducted, study design, study tool (assess neighbourhood environment), exposure assessment (any of the neighbourhood environment attributes), outcome assessment (CVD outcomes or risk factors), and measures of association. Data abstraction, classification, and quality assessment of each study were conducted by two reviewers independently. A third reviewer was consulted if there was disagreement.

### 2.2.4 Quality appraisal of the studies

In order to assess the methodological quality for each study selected , the 'Strengthening the reporting of observational studies in epidemiology' (STROBE) checklist [19] was adapted in accordance with the objectives of this study. For instance, this included the: sample size, setting, design, study tool (assessing neighbourhood environment), exposure, outcome measure and association according to the area of this study. The final PRISMA checklist included I8 items that assessed the quality of this study. Each item scored one point if full reporting was met, or zero if not or partially reported.



### 2.2.5 Data synthesis

Due to differences in research questions, exposure measurements, outcome measurements and methods across studies, a formal meta-analysis was not possible. Thus, the current review applied a semi-quantitative procedure [7]. The aim of this semi-quantitative procedure was to allow a rapid assessment of the strength of the evidence of an association between the exposure and the outcomes of interest by reducing a range of results from heterogeneous analytical designs to two binary questions [20]: a) did the study under review show a positive or negative association between the built environmental attributes and the outcome of interest? b) and, if so, was this finding statistically significant ($p<0.05$)? Hence, estimates of associations between neighbourhood environment attributes, CVD risk factors and major outcomes were extracted from the eligible studies according to their substantive relevance and methodological findings and results summarized (Table 2.3). However, to take into account potential publication bias, we did not limit our analysis on papers published in peer-reviewed journals. References of finally included records were additionally checked. Built environment studies assessing relationship with CVD risks and outcomes are relatively recent. Therefore, this study restricted the search for a specific time period and database. Contrary, no quantitative assessment for risk of bias in individual studies was performed. However, in each study sample size, number of observations per built environment and total number of considered CVD risks and outcomes were checked, because small sample sizes result in biased effect estimates.

## 2.3 Results

### 2.3.1 Overview of the study selection process



An overview of the types of the articles selected is provided in Table 2. 3, highlighting the author, country, gender, age, sample size, study design, study tools (assess neighbourhood environment), exposure measures, outcome measures and their associations. The electronic search yielded 565 articles from the selected databases; MasterFile Premier = 118, CINAHL = 71, Science Direct = 323, EBSCO (including; Academic Search, CINAHL, Global Health, Health Source: Nursing/academic, and Medline) = 47, manual search = 6. After title/abstract screening, 525 articles were excluded for not meeting inclusion criteria. Of the excluded articles, 510 articles were unrelated to neighbourhood environmental attributes, CVD risk and CVD outcomes, 5 were systematic reviews, 6 were conducted in a population with clinical conditions (disability), and another 4 were duplicates. The abstracts of 40 citations were then obtained and retrieved. Out of these abstracts, 11 were excluded since 4 were qualitative in design and 7 were conducted among adolescents. Thus, 29 full text articles were assessed for eligibility. Of these, 11 were excluded as 7 did not use NEWS, 2 were conducted among adolescents and another 2 did not meet the objective of the review to measure BE (appendix, Table 2.4). Therefore, only 18 articles were finally eligible for inclusion in the current review. The flow chart in Figure 2.1 shows the process leading to the number of included articles for the review.

### 2.3.2 General characteristics of the studies included

Table 2.3 depict the descriptive characteristics of the included studies. The year of study ranged between 2005 [21] and 2015 [22], with 27.8% (n=5) being published in 2012 [23-27]. Sample sizes varied across studies, ranging from 102 [21] to 4,319,674 [28]. In all, 55.5% (n=10) of the studies were conducted in urban [21,23,24,26,28-32,37] areas as compared to rural [33], suburban [27] and urban/suburban/rural [34]. Community based studies [22,25,37,38] constituted 22.2% (n=4) compared to one institution based study [35]. The reported ages of the participants ranged from 18 [25,27,32,37] to 80 years [28]. Most studies included females and males [21, 22,24,25,27-38] (88.9%; n=16) with only 11.1% (n=2) being in females only [23,26]. Sixteen studies (88.9%) were conducted in high-income countries [21-33,36-38], 11.1% (n=2) in middle income countries [34,35] and 38.9% (n=7) were conducted in the USA alone [21,23,25,26,31,37,38]. Of all included studies, 94.4% (n=17) were cross-sectional [21-22,26,27,29-35-38] with one being longitudinal [28].

### 2.3.3 CVD risk factors and outcomes covered across studies

Of the 18 studies reviewed, 44.4% focused on physical activity [21,23-25,29,30,34,35], 16.7% on body mass index [23,34], 5.6% on blood pressure [26], 5.6% on diabetes mellitus [37] and

16.7% on metabolic syndrome [27,33,32]. Furthermore, 16.7% of studies [22,28,36] focused on coronary heart disease, stroke and heart failure, Table2.3.

### 2.3.4 Measurement of neighbourhood environmental attributes

The majority of the studies (66.7%) used GIS [22,24,26,28,30-36-38] to assess neighbourhood environment attributes, while 33.3% used NEWS questionnaires [21,23,25,27,29,35] (Table 2.3).

### 2.3.5 Association between neighbourhood environment attributes and CVD risk

The majority of the reported associations of neighbourhood environmental attributes with CVD risk factors and outcomes were statistically significant ($p < 0.05$) with effect estimates in the expected direction, and only two studies with mixed results, comparing neighbourhood environmental attributes with transport-related physical activity [35] and hypertension [33] respectively, reported no significant association, Table 3. Forty-four percent of studies [21,23-25,29,30,34,35] reported variety of a neighbourhood environmental attributes associated with physical activity domains. Additionally, 11.1% of studies reported neighbourhood environmental attributes were associated with body mass index [23,38] and blood pressure [26,31], 16.6% with metabolic syndrome [27, 32,33] and only one study with diabetes mellitus [37]. Similarly, 16.6% of studies showed a significant association between neighbourhood environmental attributes and myocardial infarction, coronary heart disease, congestive heart failure, angina and stroke [22, 28,36], Table 2.3.

## Table 2.3 Studies that have assessed neighbourhood environmental attributes and CVD* risk factors and outcomes

| | Research Methodology | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Author (s)/year** | **Country** | **Setting** | **Gender** | **Age** | **Sample** | **Study design** | **Tool** | **Exposure measure** | **Outcome measure** | **Association** |
| Adams et al., 2012[23] | USA | Urban | F | 66-77 | 368 (Baltimore)<br>360 (Seattle) | C-S | NEWS | Land-use mix-diversity, access to services, infrastructure for walking/cycling, aesthetics, traffic safety, and crime safety | PA<br>BMI | Neighbourhood attributes differed by as much as 10 minutes/day for moderate-to-vigorous PA, 1.1 hours/week for walking, and 50 minutes/week for leisure PA ($p \leq 0.001$).<br>BMI was lower in the high walkable/recreational dense neighbourhoods ($p \leq 0.001$). |
| Witten et al., 2012**[24]** | New Zealand | Urban | F/M | 20-65 | 2,033 | C-S | GIS | Residential density, street connectivity, land use mix | PA | 1-SD increases in destination access, street connectivity, and dwelling density were associated with self-reported transport, leisure, or walking PA, with increased odds ranging from 21% (street connectivity with leisure PA, 95%-CI: 0%, 47%) to 44% (destination accessibility with walking, 95% CI: 17%, 79%). |
| Hanibuchi et al. 2011**[**34**]** | Japan | Urban/suburban/rural | F/M | 65+ | 9,414 | C-S | GIS | Residential density, street connectivity, number of local destinations, access to recreational spaces, and land slope | Leisure time, sports activity and total walking time | Population density and presence of parks or green spaces had positive associations with PA |
| Heesch et al. 2014[29] | Australia | Urban | F/M | 40-45 | 11,036 | C-S | NEWS-A | Traffic volume, aesthetics, and crime, recreational facilities, traffic slowing device, cul-de-sacs, four-way intersections, hilly streets | Cycling | Perceived environmental attributes were positively associated with cycling ($p < 0.05$). |
| Wilson et al. 2011[30] | Australia | Urban | F/M | 40-65 | 10,286 | C-S | GIS | Public transport, shop, and park street lights, river or coast connectivity, residential density, hilliness, tree coverage, bikeways, and network distance to nearest river or coast, public transport, shop, and park. | Total Minutes walking in the past week | Walking was positively associated with connectivity, residential density, least tree coverage, bikeways and streetlights. |
| Martinez et al.,2012[25] | USA | Community | F/M | 18-65 | 672 | C-S | NEWS | Neighbourhood Safety (heavy traffic, crime, stray dogs, street lights and crosswalks), socio support | LTPA | Neighbourhood attributes were negatively associated with meeting LTPA guidelines. |
| Zhou et al. 2013**[**35] | China | Schools | F/M | 40+ | 478 | C-S | NEWS-A | Residential density, diversity of land use, facility access, street connectivity, walking and cycling facilities, aesthetics, pedestrian safety, and crime safety | PA | Participants from downtown areas were more likely to engage in transportation related PA and leisure-time PA than respondents living in the suburbs. Residential density was positively associated with recreational or leisure-based PA. Street connectivity was negatively associated with leisure time PA. Moderate vigorous PA was negatively associated with traffic safety. Environmental attributes were not significantly associated with transportation PA. |
| Atkinson et al. 2005[21] | USA | Urban | F/M | 20–65 | 102 | C-S | NEWS | Land-use mix-diversity, access to services, infrastructure for walking/cycling, aesthetics, traffic safety, and crime safety | PA | Environment attributes were significantly associated with both vigorous-intensity self-reported and objectively measured physical activity. The vigorous and total activity accelerometer measures were correlated with street connectivity. |
| Pruchno et al. 2014[38] | USA | Community | F/M | 50-74 | 5688 | Survey | GIS | Supermarkets, grocery stores, local convenience stores, and fast-food restaurants | BMI | High densities of fast-food restaurants were positively associated with obesity. Supermarkets were not associated with obesity. |
| Drewnowski et al. 2012[26] | USA | Urban | F | 50-79 | 60,775 | Survey | GIS | Density of grocery store and supermarkets and fast food restaurants (1.5 miles) | Blood Pressure | High densities of stores/supermarkets were associated with low diastolic blood pressure. |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Li et al. 2009[31] | USA | Urban | F/M | 50-75 | 1,145 | C-S | GIS | Land use mix, street connectivity, number of public transit stations, and amount of green and open spaces. Density of fast-food restaurants, | Blood Pressure | High walkable neighbourhoods were associated with decreased systolic and diastolic blood pressure. Neighbourhoods of low walkability but with high density of fast-food restaurants were significantly associated with BP. The negative effect of fast-food restaurants on blood pressure was attenuated in high-walkable neighbourhoods. |
| Baldock et al. 2012[27] | Australia | Suburban | F/M | 18 + | 1,324 | C-S | NEWS-AU | Land-use mix-diversity, access to services, infrastructure for walking/cycling, aesthetics, traffic safety, and crime safety | Metabolic syndrome | Metabolic syndrome was negatively associated with local land-use mix, positive aesthetics, and infrastructure for walking, and was positively associated with perceived crime and barriers to walking. |
| Müller-Riemenschneider et al. 2013[33] | Australia | Rural | F/M | 25 + | 5,970 | C-S | GIS | Residential density, street connectivity, land use mix | Metabolic syndrome | High walkable neighbourhoods were associated with low obesity and type-2 diabetes mellitus, but not with hypertension. |
| Coffee et al. 2013[32] | Australia | Urban | F/M | 18 + | 3593 | C-S | GIS | Walkability, index-dwelling density, intersection density, land-use mix and retail footprint | Metabolic syndrome | High walkability neighbourhoods were associated with lower cardiometabolic risk. |
| Sundquist et al. 2014[37] | Sweden | Urban | F/M | 18 + | 512,061 | Survey | GIS | Residential density, street connectivity, land use mix | Type 2 diabetes | Walkability was negatively associated with type 2 diabetes. |
| Kan et al. 2008[36] | USA | Communities | F/M | 45-64 | 13,309 | survey | GIS | Traffic density/distance to major roads | CHD | High traffic density was positively associated with CHD. |
| Hamano et al. 2013[28] | Sweden | Urban | F/M | 35-80 | 4,319,674 | Longitudinal | GIS | Fast food restaurant, bars/pubs, PA and healthcare facilities | Stroke | High density fast food restaurants and pubs/bars were positively associated with stroke. Physical activity and healthcare facilities were negatively associated with stroke.. |
| Chum & O'Campo 2015[22] | Canada | Community | F/M | 25+ | 2411 | C-S | GIS | Violent crimes, environmental noise, and proximity to a major road, food stores, parks/recreation, fast food restaurants | MI, angina, CHD, stroke, and CHF | High crime rate, environmental noise, and proximity to a major road were positively associated with increased CVDs. Reduced access to food stores, parks/recreation, and increased access to fast food restaurants were associated with increased CVDs. |

**CVD, cardiovascular disease; F, female; M, male; CS, cross-section; NEWS-AU, neighbourhood environment walkability scale-Australia; PA, physical activity; BMI, body mass index; GIS, geographic information system; LTPA, leisure time physical activity; MI, myocardial infarction; CHD, Coronary heart disease; CHF; coronary heart failure.*

## 2.4 Discussion

This review has shown that varieties of neighbourhood environmental attributes are associated with physical activity. Furthermore, density of fast food restaurants, supermarkets/grocery stores and high walkable neighbourhood environments were associated with body mass index, blood pressure, diabetes mellitus and metabolic syndrome. In addition, high-density traffic, road proximity and high density of fast food restaurants were associated with major CVD outcomes.

Our results are consistent with other studies [11,39]. In particular, physical activity was associated with safe footpaths for walking [40] and access to recreational facilities [ 41,42]. The results indicate that urban attributes such as street connectivity, residential density, recreational facilities and availability of traffic devices improves neighbourhood walkability which may promote walking, leisure- and transport-related physical activity and, consequently, lowers the prevalence of CVDs. For instance, environmental attributes are thought to increase active transportation and lessen the need for private automobile use to accomplish daily tasks, which, in turn, lowers body mass index [43].



This review found that neighbourhood environmental attributes such as fast-food restaurants and high walkable neighbourhood environment were associated, either positively or negatively with body mass index, blood pressure and metabolic syndrome risk. Previous studies have reported similar results on the association between food environment and BMI [41,44,45] or blood pressure [10]. Greater accessibility to fast food restaurants may encourage people to make food choices at odds with 'healthy' dietary recommendations by making these choices easier [46].

Another explanation is that limited access to supermarkets may incentivize visits to convenience stores or fast food restaurant outlets [47], thereby increasing the chance of consuming unhealthy foods, with consequential increases in individual body mass indices and blood pressure levels.

Living in high walkable neighbourhoods was associated with a lower prevalence of high body mass index, diabetes mellitus and metabolic syndrome risk. Similar results have been reported elsewhere [10]. Neighbourhood environmental attributes may promote active transportation thus lower the CVD risks [43]. For example, a higher population density may support increased recreational opportunities and supermarkets offering a better supply of healthy foods, and so explaining associations between body mass index [48] and metabolic syndrome risk [10]. Moreover, high walkable neighbourhood environments are associated with promoting recreational and transport related physical activity [49], participation in which eventually assists in lowering the prevalence of obesity or metabolic syndrome risks. Furthermore, an increase in intersection density in the neighbourhood may promote walking through providing more route options and by helping to regulate traffic [48].



Our study also observed that major CVD outcomes are related to BE attributes. Specifically, a study has reported similar results on proximity to traffic [50]. Environmental attributes include proximity to stores, and access to supermarkets and non-fast food stores which may, consequently, affect the extent to which individuals walk and the food choices they make, which governs their diet and thus links to CVDs [51, 52]. Likewise, high traffic volumes have been associated with noise and air pollution which are linked to major CVDs. In addition, road proximity has been linked with low individual and neighbourhood socioeconomic status, both of which have been shown to be associated with CVDs [53].

## 2.5 Limitations and strengths of the study

One limitation of this study is the paucity of primary research on the association between neighbourhood environmental attributes and CVD risk and major CVDs in an African context. Almost all publications included in the review were cross-sectional, thus causal inferences in the relationships could not be determined. The exclusion of studies not conducted in English also detracts from this study. In addition, this study reviewed few CVD risk factors with selected CVDs. Future studies should explore any association between CVDs and other environmental attributes such as tobacco use, alcohol use and air pollution in order to have a broader understanding of other moderating effects. To our knowledge, this is the first review to document the associations between both objectively and subjectively measured built environment attributes and selected CVD risk and major CVDs. Methods of classification and categorization of the findings in this study follow those of other similar studies, facilitating comparisons. Moreover, this study further contributes to illustrating that studies from developed countries use comparable methodologies to studies from less well developed countries, such as this one. Thus, the current study will play a major role in the development of physical activity infrastructure in Africa.

## 2.6 Conclusion

This study shows that both objective and perceived neighbourhood environmental attributes are linked to CVD and its risk factors. The information gathered here from studies that explored neighbourhood environmental attributes and their association with CVD risks and major CVD outcomes will help guide policy makers on the neighbourhood environmental, transportation, health and education to improve intervention programmes by local government and for people at a ‘grass-roots’ level. Future studies should further explore the associations of CVD risk and CVD outcomes with a broad set of neighbourhood attributes using a longitudinal approach to better understand the direction of effects.

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# Chapter 3

## Prevalence and socio-demographic correlates of physical activity levels among South African adults in Cape Town and Mount Frere communities in 2008-2009

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## Abstract

**Background:** Physical activity has been linked to reduced risk of various cardiometabolic disease, cancer, and premature mortality. We investigated the prevalence and socio-demographic correlates of physical activity among adults in urban and rural communities in South Africa. Methods: This was a cross-sectional survey comprising 1733 adults aged ≥35 years from the Cape Town (urban) and Mount Frere (rural) sites of the Prospective Urban Rural Epidemiology study. Physical activity was assessed using the validated International Physical Activity Questionnaire. Multinomial logistic regressions were used to relate physical activity with socio-demographic characteristics.

**Results**: Overall, 74% of participants engaged in moderate-to-vigorous physical activity. In the adjusted regression models, women were 34% less likely to engage in vigorous physical activity (OR = 0.66, 95%-CI = 0.47-0.93). Physical activity decreased with age, varied with marital status, education and occupation, always in differential ways between urban and rural participants (all interactions $p \leq 0.047$). For instance, in urban settings, those with secondary education were more likely to engage in moderate physical activity (OR = 2.06, 95%-CI = 1.08-3.92), and single people were more likely to engage in vigorous physical activity (OR = 2.10, 95%-CI = 1.03-4.28). Overall, skilled participants were more likely to engage in vigorous physical activity (OR = 2.07, 95%-CI = 1.41-3.05) driven by significant effect in rural area (OR = 2.70, 95%-CI = 1.51-4.83). Urban participants were more likely to engage in moderate physical activity (OR = 1.67, 95%-CI = 1.31-2.13).

**Conclusions**: To prevent chronic diseases among South Africans, attention should be paid to specific policies and interventions aimed at promoting PA among young adults in rural and urban setting, and across the social-economic diversity.

**Key words:** Physical activity, socio-demography, determinants, rural, urban, adult, non-communicable diseases, South Africa.

## 3.1 Introduction

The health benefits of physical activity (PA) in the prevention and control of non-communicable diseases (NCDs) are well established [1]. Participation rates in PA, however, remain low in all age groups [2]. For example, more than 60% of adults worldwide do not reach recommended 150 minutes per week of moderate-to-vigorous PA required to be of benefit to their health [3,4]. It is estimated that physical inactivity defined as any activity insufficient to meet current global recommendations [5], indirectly causes 9% of premature mortality; it was linked to approximately 1.3 million of the 57 million deaths that occurred worldwide in 2008 [4]. For instance, physical inactivity could account for 6% of coronary heart disease, 7% of type 2 diabetes and 10% of cancer [4], making it the fourth leading cause of NCDs [3]. In South Africa, 3.3% of all deaths in 2000 were attributable to PA, ranking it 9$^{th}$ among other risk factors [6]. The prevalence of self-reported physical inactivity is high in both developed countries like the United States, where 32% of adults are physically inactive [7], and in developing countries such as South Africa were 45% adults were reported to be inactive [8]. Other African countries also report a high prevalence of physical inactivity among adults, 49.1% and 52.6% in Swaziland and Mauritania respectively [8].



Similar to other developing countries, South Africa is currently undergoing nutritional, lifestyle, and socioeconomic transitions, with increases in the occurrence of NCDs [9]. Non-communicable diseases of lifestyle share similar modifiable risk factors, which include hypertension, tobacco smoking, diabetes, obesity, hyperlipidaemia and physical inactivity [10]. Physically inactivity in global populations represents a major public health challenge [4]. Documented research comparing activity levels in urban and rural settings suggests that rural adults tend to be less active than their urban counterparts, although findings have been inconsistent [11]. In the USA, a study revealed that PA levels were higher in urban areas than in rural areas [12]. Similarly, in South Africa, subjects in isolated rural areas were found to be more inactive than their urban-dwelling counterparts [10]. Again, similar results were also reported in a study of Kenyan adolescents [13]. Conversely, a South African Demographic and Health Survey found that urban youths were more likely to be physically inactive, than rural ones [14].

The importance of promoting physical activity in populations is reflected by the South Africa National Strategic Plan for the Prevention and Control of non-communicable diseases, which targets a 10% reduction in the prevalence of inactivity by 2020 [15]. Indeed, a recommendation for every adult to accumulate 30 minutes or more of moderate-to-vigorous intensity physical activity on as many days and, preferably, every day of the week [16] is estimated to increase the life expectancy of the world's population [4].



However, in order to understand PA patterns and make positive changes to them, it is important to understand the independent contributions of urban-rural and socio-demographic risk factors [17]. Conducting population-based studies on prevalence of physical activity and its determinants is necessary to identify the relevant areas in local environments that need change, areas where currently such information is scarce [18]. In this study, we determine the prevalence of self-reported PA and associated socio-demographic factors among South African adults in urban and rural communities.

## 3.2 Methods

### 3.2.1 Study population

This cross-sectional study uses data from the Cape Town (urban) and Mount-Frere (rural) sites of the global Prospective Urban and Rural Epidemiology study (PURE) study. PURE is a multinational cohort study that tracks societal influences, risk factors and chronic non-communicable diseases in urban and rural areas across 17 countries including South Africa. PURE collects baseline data on countries' characteristics (e.g. economic environments), communities (e.g. nutritional environment), households (e.g. income) and individual determinants (e.g. diet and physical activity) [19]. During a baseline evaluation conducted by PURE in 2008-2009, a representative random sample of adults was selected from well-established rural (Mount Frere) and urban (formal settlements in Cape Town) communities in South Africa. The household inclusion criteria were: (1) to have at least one member who was aged 35-70 years, (2) to be within an identified neighbourhood and (3) to not have members with a disability that precluded walking.



### 3.2.2 Ethical considerations

The study was conducted according to the Helsinki principles [20]. The Senate Higher Degrees committee, Research Committees of the University of the Western Cape (UWC), South Africa and the *Population Health Research Institute (*PHRI) in Canada approved this study (Registration **#13/6/18**). An information sheet translated into Xhosa was issued to the respondents concerning the purpose of the PURE study. To ensure confidentiality, only researchers handled data. The respondents remained anonymous. Participation was voluntary, participants were entitled to refuse to answer a question and could withdraw from the study at any point. The name and contact details of the researchers were included in the information sheet. A consent form to take part in the survey was signed by all participants.

### 3.2.3 Data collection

Participants were interviewed in the language of their choice. We used structured, socio-demographic and lifestyle questionnaires that were developed and standardized for the international PURE study [19]. The questionnaires were completed during home visits by trained field workers. Repeated visits at different times of the day to households where individuals were missed were used to reduce the level of non-response. Physical examination included anthropometric measures (height, weight, waist and hip circumference) [21]. 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 0-120 kg. Body mass index (BMI) was calculated as weight (kg) divided by the square of the height ($m^2$). The World Health Organization [22] principal cutoff points for BMI were used to create the categories: underweight (< 18.5 kg/$m^2$), normal weight (18.5- < 25 kg/$m^2$), overweight (25-< 30 kg/$m^2$) and obese (> 30 kg/$m^2$). In all consenting and eligible individuals, the long version of the International Physical Activity Questionnaire (IPAQ) was used to measure self-reported PA [23].

### 3.2.4 Socio-demographic characteristics

We recorded socio-demographic information, specifically: age, sex, marital status, education level, and occupation from each participant. We grouped them into four age categories: 35 to 44 years, 45 to 54 years, 55 to 64 years and 65 years or older. Marital status was classified as never married, currently married, and widowed/divorced/separated. Education level was classified as primary, secondary and tertiary education. Occupational status ranged from 1 to 11 items prompted by the following statement; "*Please indicate which group best describes your main occupation*". In this study, the occupation status was then categorized as skilled (technicians, machine operators, clerks, skilled agriculture and fishery workers) and less skilled (homemaker, service, shop and market workers).

### 3.2.5 Physical activity measure

The IPAQ includes questions on frequency and duration of vigorous and moderate intensity physical activities, and walking in terms of the frequency (days/week) and duration (min/day) in the last 7 days. The physical activities were classified into the domains of work-related, transport-related, household-related and leisure activity for each category of walking, moderate and vigorous-intensity. Weekly minutes of walking, moderate-intensity and vigorous-intensity activity were calculated separately by multiplying the number of days/week by the duration on an average day. In this study, physical activity levels were classified as low, moderate, or high intensity, defined by the IPAQ core group (http://www.ipaq.ki.se) as follows: Low - no activity or some activity reported, but not enough to satisfy the requirements of the other activity categories; Moderate - any of the following 3 criteria: (a) 3 or more days of vigorous-intensity activity for at least 20 minutes per day, (b) 5 or more days of moderate intensity activity or waking for at least 30 minutes per day, or (c) 5 or more days of any combination of walking, moderate intensity, or vigorous-intensity activities achieving a minimum of 600 MET-minutes per week; High - either of the following 2 criteria: (a) 3 or more days of vigorous-intensity activity accumulating at least 1500 MET-minutes per week or (b) 7 days of any combination of walking or moderate- or vigorous intensity activities achieving a minimum of 3000 MET-minutes per week. Acceptable test retest reliability and criterion validity compared with accelerometer monitoring has also been reported for IPAQ in both the developed and developing countries [24].

### 3.2.6 Statistical analysis

The starting sample comprised 2064 participants of whom 316 were excluded for unacceptable levels of missing data [25]. A further 15 participants aged less than 35 years were excluded, making a final analytic sample of 1733 participants. We used SPSS® version 22 for Windows (IBM Corp: Armonk New York) for all statistical analyses. Chi-squared tests were used to compare socio-demographic characteristics and physical activity. We used multinomial logistic regressions to investigate the determinants of physical activity, with low physical activity as the reference, both in univariate and multivariate models. The differential effects of socio-demographic characteristics on physical activity levels according to urban and rural setting were assessed through interaction tests. Statistical significance was set at $p < 0.05$.

## 3.3 Results

### 3.3.1 General characteristics and pattern of physical activity

Table 3.1 shows the overall and site-specific (urban/rural), socio-demographic characteristics and the prevalence of PA among the participants. Participants were evenly divided between urban (50.6%) and rural (49.4%) sites. Women comprised the majority of the sample in rural (76.8%) and urban (71.4%) sites and overall (74%) and their proportional was significantly higher than that of men ($p = 0.011$). The most common age group was 45-54 years (33.1%), and age distribution did not differ across sites ($p = 0.375$). Obesity (BMI $\geq$ 30 $kg/m^2$) was higher in the urban site at 57%, versus 42% in the rural site and differences were significant ($p < 0.001$). There were significant differences between urban and rural sites for categories of education, marital status and occupation (all $p < 0.001$), Table 3.1. Patterns of PA were 31%, 51.5% and 17.5% in the rural site; 20.9%, 61.2% and 17.9% in the urban site and 25.9%, 56.4% and 17.7% per day in combined sites for low, moderate and vigorous PA respectively in each case, and differences between sites were significant ($p < 0.001$), Table 3.1.

**Table 3.1 Socio-demographic characteristics of adults South Africans from Cape Town and Mount Frere communities in 2008-2009**

| Variables | Urban (n=877) (%) | Rural (n=856) (%) | P-value | Overall (N=1733) (%) |
|---|---|---|---|---|
| **Gender** | | | **0.011** | |
| Female | 71.4 | 76.8 | | 74.0 |
| Male | 28.6 | 23.2 | | 26.0 |
| **Age** | | | 0.375 | |
| 35-44 | 30.1 | 31.5 | | 30.8 |
| 45-54 | 35.0 | 31.1 | | 33.1 |
| 55-64 | 26.0 | 27.6 | | 26.8 |
| 65 and above | 8.9 | 9.8 | | 9.3 |
| **BMI ($kg/m^2$)** | | | **<0.001** | |
| <18.5 | 3.7 | 2.8 | | 3.2 |
| 18.5-24.9 | 21.1 | 28.2 | | 25.3 |
| 25.0-29.9 | 18.2 | 27.3 | | 23.6 |
| >30.0 | 57.0 | 41.7 | | 47.9 |
| **Education level** | | | **<0.001** | |
| Primary | 23.8 | 49.9 | | 36.7 |
| Secondary | 69.1 | 47.3 | | 58.3 |
| Tertiary | 7.1 | 2.8 | | 5.0 |
| **Marital status** | | | **<0.001** | |
| Single | 51.2 | 30.8 | | 41.1 |
| Married | 33.6 | 44.7 | | 39.1 |
| Widowed/divorced/separated | 15.2 | 24.4 | | 19.7 |
| **Occupation** | | | **<0.001** | |
| Skilled | 22.2 | 14.6 | | 18.5 |
| Less skilled | 77.8 | 85.4 | | 81.5 |
| **Ethnicity** | | | 0.693 | |
| African | 98.7 | 98.9 | | 98.8 |
| Coloured | 1.3 | 1.1 | | 1.2 |
| **Physical activity levels** | | | **<0.001** | |
| Low | 20.9 | 31.0 | | 25.9 |
| Moderate | 61.2 | 51.5 | | 56.4 |
| Vigorous | 17.9 | 17.5 | | 17.7 |

Bold is significant p value

### 3.3.2 Socio-demographic characteristics and physical activity levels

#### 3.3.2.1 Gender and physical activity

Table 3.2 shows the PA patterns for each socio-demographic category. Overall, 26.9% of women engaged in low PA compared to 22.9% of men. More women (56.9%) engaged in moderate PA than men (55.1%), but fewer women (16.2%) engaged in vigorous PA than men (22.0%) and these differences were significant ($p = 0.014$). In stratified analysis, the pattern of PA differed between men and women in the rural site ($p = 0.031$), but not in the urban site ($p = 0.371$).

#### 3.3.2.2 Age and physical activity

In the rural area, 54.6% of those aged 65 years and above engaged in low PA, 57.1% of those aged 45-54 years engaged in moderate PA and 25.6% of those aged 35-44 years engaged in high PA ($p < 0.001$). There was a slight tendency for differences in the distribution of PA across age groups in the urban site ($p = 0.057$), Table 3.2. Among age groups in the sites combined, 43.8% of participants aged 65 years and over engaged in low PA, 58.2% of those aged 55-64 years engaged in moderate PA and 21.5% of those aged 35-44 years engaged in high PA. These differences were significant ($p < 0.001$).

#### 3.3.2.3 Education and physical activity

Overall 30.5% of participants with primary education engaged in low PA, 55.0% in moderate PA and 19.3% with tertiary education engaged in vigorous PA ($p = 0.003$), and these differences were also evident in the urban site ($p = 0.009$), but not in the rural ($p = 0.167$), Table 3.2.

#### 3.3.2.4 Marital status and physical activity

Among the widowed, divorced or separated participants, 33.6% engaged in low PA, while 57.8% of single participants engaged in moderate and 20.8% in vigorous PA ($p < 0.001$). This pattern was similar in the urban site ($p = 0.010$), but not in the rural site ($p = 0.086$). In the urban site, 28.6% of those widowed, divorced or separated engaged in low PA, while 61.7% of single participants and 61.7% of married participants engaged in moderate PA, Table 3.2.

#### 3.3.2.5 Occupation and physical activity

In the overall sample, 27.0% of less skilled and 20.9% of skilled participants engaged in low PA. Equivalent figures were 57.8% and 50.3% for moderate PA and 15.1% and 29.1% for vigorous PA ($p < 0.001$). The pattern with occupation was mostly similar and differences were significant when stratified by site ($p < 0.001$ in both sites), Table 3.2.



#### 3.3.2.6 Location and physical activity

Of all participants, 31.0% in the rural area and 20.9% in the urban area engaged in low PA. Contrarily, 61.2% and 51.5% of participants in urban and rural areas respectively engaged in moderate PA. Proportions of participants that engaged in vigorous PA were similar in urban (17.9%) and rural (17.5%) areas. The differences between settings were significant ($p < 0.001$), Table 3.2.

**Table 3.2 Socio-demographic characteristics by physical activity levels among adults South Africans from Cape Town and Mount Frere communities in 2008-2009**

| Variables | Urban (n=877) Physical activity Low (%) | Moderate (%) | High (%) | P-value | Rural (n=856) Physical activity Low (%) | Moderate (%) | High (%) | P-value | Overall (N=1733) Physical activity Low (%) | Moderate (%) | High (%) | P-value |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Gender** | | | | 0.371 | | | | **0.031** | | | | **0.014** |
| Women | 21.4 | 61.8 | 16.8 | | 32.1 | 52.2 | 15.7 | | 26.9 | 56.9 | 16.2 | |
| Men | 19.5 | 59.8 | 20.7 | | 27.1 | 49.2 | 23.6 | | 22.9 | 55.1 | 22.0 | |
| **Age** | | | | 0.057 | | | | **<0.001** | | | | **<0.001** |
| 35-44 | 20.5 | 62.1 | 17.4 | | 25.6 | 48.8 | 25.6 | | 23.0 | 55.4 | 21.5 | |
| 45-54 | 19.9 | 59.0 | 21.2 | | 27.1 | 57.1 | 15.8 | | 23.2 | 58.1 | 18.7 | |
| 55-64 | 18.9 | 63.6 | 17.5 | | 33.1 | 53.0 | 14.0 | | 26.1 | 58.2 | 15.7 | |
| 65 and above | 32.1 | 60.3 | 7.7 | | 54.8 | 38.1 | 7.1 | | 43.8 | 48.8 | 7.4 | |
| **Education level** | | | | **0.009** | | | | 0.167 | | | | **0.005** |
| Primary | 24.4 | 63.6 | 12.0 | | 35.5 | 50.8 | 15.9 | | 30.5 | 55.5 | 14.5 | |
| Secondary | 18.6 | 61.9 | 12.5 | | 29.4 | 51.6 | 17.2 | | 22.9 | 53.8 | 19.3 | |
| Tertiary | 30.6 | 46.8 | 22.6 | | 12.5 | 62.5 | 25.0 | | 25.6 | 51.2 | 23.3 | |
| **Marital status** | | | | **0.010** | | | | 0.086 | | | | **<0.001** |
| Single | 17.1 | 61.7 | 21.2 | | 28.8 | 51.1 | 20.1 | | 21.5 | 57.8 | 20.8 | |
| Married | 23.1 | 61.7 | 15.3 | | 29.2 | 52.0 | 18.8 | | 26.5 | 56.2 | 17.3 | |
| Divorced/separated | 28.6 | 58.6 | 12.8 | | 36.8 | 51.2 | 12.0 | | 33.6 | 54.1 | 12.3 | |
| **Occupation** | | | | **<0.001** | | | | **<0.001** | | | | **<0.001** |
| Skilled | 21.0 | 51.8 | 27.2 | | 20.0 | 48.0 | 32.0 | | 20.6 | 50.3 | 29.1 | |
| Less skilled | 20.8 | 63.9 | 15.2 | | 32.8 | 52.1 | 15.0 | | 27.0 | 57.8 | 15.1 | |
| **Location** | | | | | | | | | | | | **<0.001** |
| Urban | | | | | | | | | 20.9 | 61.2 | 17.9 | |
| Rural | | | | | | | | | 31.0 | 51.5 | 17.5 | |

Bold is significant p value

#### 3.3.2.7 Multivariable regression analysis and interaction tests

Table 3.3 shows odds ratios from age and sex-adjusted multinomial regression analyses of socio-demographic characteristics and PA. In these models, when applied to all participants, age ($p < 0.001$), occupation ($p < 0.001$) and location ($p < 0.001$) were significantly associated with PA level, while there was a borderline association with gender ($p = 0.055$), and no association with education ($p = 0.116$) or marital status ($p = 0.126$), Table 3.3. With the exception of gender ($p = 0.072$), significant interactions were observed between location and socio-demographic characteristics (results not shown in the table), in their relationship with PA ($p < 0.001$ for age*location, $p = 0.012$ for education level*location, $p < 0.001$ for marital status*location, $p < 0.001$ for occupation*location interaction tests).

Overall, women were 34% less likely (OR = 0.66, 95%-CI = 0.47-0.95) to engage in high PA than men. The odds of engaging in high PA decreased with increasing age, with the effects being significant across age strata overall and in urban and rural participants. Each age category was more likely to engage in moderate and high PA than those in the category aged 65 and above, in both the overall cohort and in rural participants, but not in the urban ones ($p < 0.001$ for age*location interaction). Having a secondary education (relative to tertiary) was associated with moderate PA among urban participants only (OR = 2.06, 95% CI = 1.08-3.92).

Marital status was variably associated with PA in the overall cohort and across sites ($p < 0.001$ for the interaction marital status*location). For instance, single participants (relative to those divorced) were more likely to engage in high PA in the overall cohort and in the urban site, Table 3.3.

In the overall cohort, skilled participants (relative to less skilled) were associated with higher odds of engaging in high PA. The effect was similar in both rural and urban participants ($p < 0.001$ for occupation*location interaction).

**Table 3.3 Multinomial logistic regression result of socio-demographic characteristics by physical activity levels with reference to low physical activity in adults South Africans from Cape Town and Mount Frere communities in 2008-2009**

| | **Urban (n=877) Physical activity** | | | | | **Rural (n=856) Physical activity** | | | | | **Overall (N=1733) Physical activity** | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Moderate** | | **High** | | **p-value** | **Moderate** | | | **High** | **p-value** | **Moderate** | | **High** | | **p-value** |
| **Variables** | **OR[a]** | **95%-CI** | **OR[a]** | **95%-CI** | | **OR[a]** | **95%-CI** | **OR[a]** | **95%-CI** | | **OR[a]** | **95%-CI** | **OR[a]** | **95%-CI** | |
| **Gender** | | | | | 0.351 | | | | | 0.154 | | | | | **0.050** |
| Men | 1.00 | | 1.00 | | | 1.00 | | 1.00 | | | 1.00 | | 1.00 | | |
| Women | 0.89 | 0.61-1.32 | 0.71 | 0.44-1.14 | | 0.91 | 0.62-1.35 | **0.63** | 0.38-1.01 | | 0.91 | 0.69-1.19 | **0.66*** | 0.47-0.93 | |
| **Age** | | | | | 0.360 | | | | | **<0.001** | | | | | **<0.001** |
| 65 and above | 1.00 | | 1.00 | | | 1.00 | | 1.00 | | | 1.00 | | 1.00 | 2.07-8.13 | |
| 35-44 | 1.40 | 0.75-2.61 | 2.31 | 0.83-6.44 | | **2.66***** | 1.53-4.64 | **6.12***** | 2.40-15.62 | | **2.03***** | 1.36-3.05 | **4.06***** | 2.05-8.05 | |
| 45-54 | 1.31 | 0.70-2.48 | 2.47 | 0.88-6.94 | | **2.89***** | 1.65-5.09 | **3.29*** | 1.24-8.70 | | **2.01***** | 1.33-3.03 | **3.12***** | 1.59-6.28 | |
| 55-64 | 1.69 | 0.91-3.12 | **3.12*** | 1.13-8.60 | | **2.26**** | 1.32-3.86 | **2.98*** | 1.15-7.75 | | **1.99***** | 1.34-2.96 | **3.00***** | 1.49-6.103 | |
| **Education level** | | | | | 0.072 | | | | | 0.292 | | | | | 0.116 |
| Tertiary | 1.00 | | 1.00 | | | 1.00 | | 1.00 | | | 1.00 | | 1.00 | | |
| Primary | 1.68 | 0.82-3.42 | 1.06 | 0.43-2.64 | | 0.42 | 0.11-1.56 | 0.54 | 0.12-2.43 | | 1.26 | 0.70-2.27 | 1.05 | 0.51-2.15 | |
| Secondary | **2.06*** | 1.08-3.92 | 1.87 | 0.85-4.08 | | 0.44 | 0.12-1.69 | 0.63 | 0.14-2.73 | | 1.43 | 0.82-2.51 | 1.49 | 0.76-2.91 | |
| **Marital status** | | | | | **0.041** | | | | | 0.797 | | | | | 0.126 |
| Divorced | 1.00 | | 1.00 | | | 1.00 | | 1.00 | | | 1.00 | | 1.00 | | |
| Single | **1.66** | 0.99-2.78 | **2.10*** | 1.03-4.28 | | 0.95 | 0.60-1.50 | 1.35 | 0.72-2.53 | | 1.23 | 0.88-1.72 | **1.69*** | 1.06-2.69 | |
| Married | 1.24 | 0.74-2.07 | 1.09 | 0.53-2.26 | | 1.02 | 0.68-1.53 | 1.28 | 0.72-2.30 | | 1.10 | 0.81-1.51 | 1.20 | 0.77-1.88 | |
| **Occupation** | | | | | **<0.001** | | | | | **<0.001** | | | | | **<0.001** |
| Less skilled | 1.00 | | 1.00 | | | 1.00 | | 1.00 | | | 1.00 | | 1.00 | | |
| Skilled | 0.84 | 0.54-1.32 | **1.69*** | 1.00-2.85 | | 1.23 | 0.73-2.06 | **2.70***** | 1.51-4.83 | | 0.99 | 0.71-1.39 | **2.07***** | 1.41-3.05 | |
| **Location** | | | | | | | | | | | | | | | **<0.001** |
| Rural | | | | | | | | | | | 1.00 | | 1.00 | | |
| Urban | | | | | | | | | | | **1.67***** | 1.31-2.13 | 1.20 | 0.87-1.65 | |

*OR, odds ratios; CI, confidence interval; *p<0.05; **p<0.01; ***p<0.001; [a] Odds ratios adjusted for all variables in the table;* ***bold*** *p = significant borderline*

## 3.4 Discussion

This study provides insight into the socio-demographic correlates of PA levels in the urban and rural communities of South African adults. Over half the participants sampled engaged in moderate-to-vigorous PA. However, a higher proportion of physical inactivity was observed in the rural participants compared to those in urban areas. Urban participants were more likely to meet recommended PA guidelines for public health than their rural counterparts. Similarly, the odds of participants achieving recommended PA guidelines (moderate PA) were 76% higher in an urban than in a rural setting. The results of this study can be compared with the findings of a PA survey from 22 African countries where prevalence of PA ranged from 72.5% (Swaziland) to 96.0% (Mozambique) [8]. Similarly, 67% of urban dwelling black South African women were classified as physically active [26]. Conversely, the odds of participants being physically inactive in United States was 43% higher in the extreme rural areas compared with urban ones [12]. A study in Cameroon, however, showed that rural dwellers were significantly more active than their urban counterparts based on objectively measured physical activity [27].



A high prevalence of physical inactivity in rural areas, especially in South Africa, may be because PA is largely of low intensity there. A study conducted in KwaZulu-Natal in South Africa reported high volumes of low intensity physical activity among rural children and adolescents [28]. It is also stated that the spread of technology used across different domains of society and the shift in the predominant type of employment and lifestyle behaviour, specifically from agriculture to industries and services, contributed to a reduction in physical activity [29]. The variations of results across studies could be due to different tools used to measure physical activity. In addition, there is difficulty to understand the intent of the IPAQ questions, in recalling the information requested, and in making the calculations required to perform physical activity [30]. Furthermore, different types of PA are undertaken between and within communities that are socially, economically, geographically and religiously different across aspects of life [31]. For this reason, objective assessment especially accelerometers are ideal measures to identify physical activity in South African populations. Therefore, results of the current study should be interpreted with caution.

The overall prevalence of moderate to high physical activity did not differ significantly between genders. However, the adjusted odds ratio showed that women were 34% less likely to engage in the vigorous PA than men. A similar study found that women exhibited higher levels of inactivity than men and that inactivity was higher among older people [8]. Concurrently, a study conducted in Spain reported comparable results [32]. Conversely, studies conducted in Rwanda [33] and Nigeria [17], showed a higher prevalence of PA among women than in men.



Although it is difficult to interpret these conflicting results, South Africa could be described as a country in transition, and consequently there are currently high levels of infrastructure development, for which men are typically employed and often requires high levels of vigorous activity. Altogether, these findings suggest that women are not inactive but accumulate relatively large amounts of physical activity by participating in activities such as housework and yard work [34]. In addition, since few of these females have motor vehicles within their households, much transport is by walking which is generally not performed at intensities associated with walking for exercise [34]. Physical inactivity poses a major health risk to the South African women and with the projected increase in health risk to over 65s, an increase in morbidity and mortality in these areas is expected [35]. Hence, necessary interventions need to be implemented, among women through all age groups at societal level [35].

Our study showed that PA decreased with age, in accordance with previous studies [36, 37]. A similar study found that the volume of sedentary behaviour increased, whereas ambulatory activity [38] and recreational activity [39] decreased with age. Due to the fact that studies use different measures and definitions, direct comparisons are not possible. For example, vigorous activity have been reported to decrease with age, whereas moderate intensity activity increase from ages 13 to 27 years [40]. Furthermore, the relationship can be affected by the effect of various confounding factors such as genetic, cultural, socio-economic, nutritional factors and inactivity [41]. These act through reduction of the functional abilities, strength, and ambulation associated with increased age-related diseases. As a result, the relationship between physical activity and healthy ageing among adults still remains complex, and physical activity levels must be taken into account in ageing studies [41].



Level of education has also been associated with PA [42]. Similarly, results in this study showed that in urban areas, participants who had reached secondary level education were twice more likely to engage in moderate PA than those with tertiary education. In rural areas, participants with primary education tended to be the least likely group to engage in moderate PA. According to Cook [34], women in rural areas are more likely to accumulate their moderate PA over time such as farming activity.  These results are comparable to another study which found the level of education was associated with the likelihood of walking [43]. Thus, less educated people may be more likely to walk or cycle than the highly educated, possibly because the latter may own a car, with the associated reduction in physical inactivity. It is also likely that less educated people may be employed in jobs that are more physically demanding, while they also have insufficient money and time to engage in leisure-time PA. Contrarily, people at a higher educational level may have more sedentary jobs, but may engage more in leisure-time PA than those less well educated because they are more likely to access physical activity facilities and they understand its associated health benefits [44].

Cross-sectional studies report mixed results concerning the relationship between marital status and PA, although it is often an inverse relationship, where married individuals are less physically active than those who are unmarried [45]. This study showed that, both in the urban site and overall, a higher proportion of single participants engaged in moderate-to-vigorous PA than those who were divorced or separated, and comparable results to these were reported by a study in Lebanon [46]. There are however also reports that show married people as being more active than the single people [47], and a study based in Nigeria found a positive association between being married and reaching sufficient PA levels [18]. However, in this study, being married was not a determinant factor for PA. Contrasting results in studies of the relationship between marital status and PA could be a consequence of conflicting variables. For instance, cultural expectations of married African adults, especially men, may differ and men may be expected to be the primary earners [18] but this may not be true in all countries, such as South Africa.

Likewise, this study noted that participants with skilled jobs were more likely to engage in high PA than less skilled (or homemakers). Similarly, a study in Mexico showed that a higher percentage of adults working in agriculture and fishing were in a higher activity level category than those in lower-intensity occupational activities, the latter also having a greater proportion of participants in low and moderate activity levels [48]. A study in Australia, however, showed those participants in the lower strata of occupations to be less likely to report participation in vigorous PA sufficient to achieve cardiorespiratory fitness [49]. Most of sub-Saharan African countries, particularly those undergoing rapid developments, are in the midst of demographic and epidemiologic transitions. These developmental processes bring about changes in the social capital of societies, change working patterns and lifestyles contributing to reduction in physical activity levels [50].

## 3.5 Limitations and strengths

Our study has some limitations. Its cross-sectional design did not allow for the investigation of causal relationship among characteristics. This study was restricted to adults only, in two provinces of South Africa, and its findings may not be applicable countrywide. Finally, another limiting factor of this study was that PA was assessed with a version of IPAQ, a self-report measure associated with overestimation of PA levels [46]. Nevertheless, this study was based on a large cohort of urban and rural South Africans, primarily of African descent which was assessed using a standardized method for surveying risk factors for chronic diseases. The study adds to previous reports by providing determinants and prevalence of PA levels in an urban and rural setting in South Africa. However, future studies aiming at monitoring of the exposure to PA should consider conducting objective assessment of PA in order to validate PA in urban and rural communities.

## 3.6 Conclusions

The current study indicates that if no effective public health approach or social economic plans are implemented, further decrease in physical activity will lead to high risk of developing major chronic diseases among South Africans. Culturally or community tailored intervention to promote physical activity should target individuals at an early age, those with primary, tertiary education, married and divorced and rural residents in South Africa. Studies using objective assessment of physical activity are needed to confirm these findings.

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# Chapter 4

## Association between perceived built environmental attributes and physical activity among adults in South Africa

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## Abstract

**Background:** There is a need for greater understanding of how perceived built environment attributes influence physical activity among adult South Africans. The aim of this study was to investigate the association between perceived environmental attributes and leisure-time and transport-related physical activity.

**Methodology:** This was a cross-sectional survey involving 671 South Africans aged ≥35 years from urban and rural settings. The International Physical Activity Questionnaire and Neighbourhood Walkability Scale were used to collect data. Multivariable logistic regressions were used to determine associations.

**Results:** Significant urban vs. rural difference were apparent in the distribution of most attributes of neighborhood environment. After adjusting for gender, age and setting and relevant interaction terms, proximity to local stores was significantly associated with leisure-time physical activity (OR: 4.26; 95%CI, 1.00-18.08); while proximity to transit stops (2.44; 1.48-4.02), pleasant scenery (1.93; 1.07-3.46), sidewalks (2.36; 1.25-4.44), shade from trees (2.14; 1.19-3.85), traffic (2.17; 91.21-3.91) and well-lit streets (2.01; 1.04-3.89) were significantly associated with walking for leisure. Four-way intersections (4.54; 1.54-13.43), pleasant scenery (3.84; 1.35-10.99), traffic (0.28; 0.09-0.89), sidewalks (3.75; 1.06-13.27) and crosswalks were associated with transport related physical activity. Proximity to transit stops (2.12; 1.17-3.84) and well maintained sidewalks (2.69; 2.20-10.02) were significantly associated with total physical activity. Significant interactions by setting were apparent in some of the associations.

**Conclusion:** Some, but not all attributes of a neighborhood environment were significantly associated in expected directions with the three physical activity domains in this mixed urban

and rural population. This study highlights the need for policy strategies aimed at improving or maintaining these perceived environmental attributes to promote physical activity.

**Keywords:** physical activity, built environment, transport, leisure, walking, South Africa

## 4.1 Introduction

Regular physical activity (PA) is reported to be essential for the overall health and is associated with reduction in morbidity and mortality [1]. It is estimated that lack of physical activity accounts for between 3% and 4% of deaths among South Africans men and women respectively [2]. Consequently, 3.3% of all deaths in South Africa in 2000 were attributed to physical inactivity [3]. Moreover, 48% of South African men and 63% of South African women were reported as being physically 'inactive' (4).

Walking for transportation can assist people in meeting recommended levels of physical activity [1]. Accordingly, residents living in highly walkable neighborhoods are more likely to walk for leisure than those living in low-walkable neighborhoods [5]. These findings are supported by evidence from others studies that showed aesthetic environment, convenience of facilities for walking, accessibility, and perception about traffic and busy roads were associated with walking [6].



There is a growing body of international data showing that perceived built environments are associated with physical activity [7,8] at a population level. Perceived built environment features such as proximity to destinations, sidewalks, the presence of physically active people in the neighborhood, higher residential density, neighborhood safety [7] and aesthetic quality [9] have been associated with moderate to vigorous physical activity and walking. Similarly, access to services, street connectivity, pedestrian infrastructure, heavy traffic and a mix of utilitarian and recreational destinations have been linked to active travel, recreational physical activity [8] and leisure-time physical activity and leisure-time walking [9].

The design of built environment attributes that shape and promote active living are vital in modern society as they help town planners and policy makers to make decisions that could potentially improve physical activity at a neighborhood level [10]. However, there remains a gap in literature concerning the association between perceived built environment attributes and physical activity in an African context. For instance, with a few exceptions [11], most studies in this field originate from high income countries [12]. Therefore, the aim of this study was to investigate the association between perceived environmental attributes and leisure-time and transport-related physical activity in urban and rural communities in South Africa.

## 4.2 Methods

### 4.2.1 Study design

This was a cross-sectional analysis of the baseline data of the South African arm of the Prospective Urban and Rural Epidemiology (PURE) Study collected in 2009.



### 4.2.2 Study population and setting

The study cohort included 2064 black South African men and women, aged 35-70 years, inhabiting in rural and urban sites, and was established in 2009. Communities selection purposefully favoured communities where a follow up of each respective cohort (urban vs rural) was feasible [13]. For the urban community (Langa), households were grouped into three development areas recognized administratively by the City of Cape Town Municipality. A street map obtained from the City of Cape Town was used to randomly select streets in each of these 3 areas. Once a street was selected, a systematic sampling of every second house was used to select potentially eligible participants for inclusion in the study. In the rural community (Mount Frere), the absence of delineated streets precluded following the same sampling approach used for the urban township. A cluster sample of houses in the community was therefore selected according to the division of areas determined by the clan heads. The inclusion criteria for both urban and rural were as follows: (1) households with a minimum of one member who was aged 35-70 years, (2) houses situated within an identified neighborhood and (3) houses without occupants with a disability that precluded them from walking. The sampling yielded 437 households in the urban community (1061 individuals) and 329 households in the rural community (1003 individuals). All households with eligible individuals were approached for recruitment, by trained field workers. For this study, all members in each household who met the criteria were used for analysis.

### 4.2.3 Ethical considerations

The study was conducted according to the Helsinki principles [14]. The Senate Higher Degrees committee, Research Committees of the University of the Western Cape, South Africa and the *Population Health Research Institute*, Canada approved this study (Registration **#13/6/18**). A consent form was signed by all the participants.



### 4.2.4 Data collection

The PURE study used standardized, interviewer-administered questionnaires previously tested for anthropometric and biochemical measurements [13]. For illiterate participants, the trained filed workers completed the questionnaires during home visits. The study used the long version of the International Physical Activity Questionnaire (IPAQ) [15] and the Neighbourhood Environment Walkability Scale (NEWS) questionnaire [16].

### 4.2.5 Covariates

Socio-demographic information on age, sex, marital status, education level, and occupation were elicited from participants using a self-administered questionnaire. Participant age was grouped into 3 categories: 35 to 44, 45 to 54, and 55 years or older. Marital status was classified as single, married, or divorced. Education level was classified as primary, secondary and tertiary. Occupation was categorized as skilled (technicians, machine operators, clerks, skilled agriculture and fishery workers) and less skilled (homemaker, service, shop and market workers).

### 4.2.6 Self-reported physical activity

The interviewer administered the long IPAQ to collect data on self-reported leisure-time and transport-related physical activity [17]. The IPAQ long form questionnaire assesses physical activity across a comprehensive set of domains including leisure time, domestic and gardening (yard), work-related, and transport-related physical activities, over the last 7 days. The IPAQ questionnaire was used to measure the frequency (days) and duration (in minutes) of vigorous-intensity PA, moderate-intensity PA, and walking-level PA separately. The total number of minutes per week in each PA category was computed (http://www.ipaq.ki.se). In the present study, four outcome variables [18] were calculated: (1) leisure-time physical activity, (2) transport-related physical activity, (3) walking for leisure and (4) total physical activity.

In this study, the four outcome variables were dichotomized into <150 minutes and ≥150 minutes according to WHO PA recommendations [19]. A 12-country, 14 site study showed that the long IPAQ has excellent one-week test-retest reliability (pooled $r$ = 0.81) and acceptable validity (pooled $r$ = 0.33) when compared with accelerometer-measured physical activity [20,]. More recently, the test-retest reliability attributes of the NEWS questionnaire adapted to African urban settings have also been confirmed [21].

### 4.2.7 Self-perceived built environment

Participants completed interviewer-administered NEWS questionnaires [22] which assess the perceived built environment on the following selected variables: land use mix–access (4 items), walking/cycling infrastructure (3 items), aesthetics (3 items), traffic (3 items) and crime (3 items). Participants were instructed to consider neighbourhood as the area within a 15–20 min walk from their home. These items used 4-point Likert scale-type of responses ranging from strongly disagree (1) to strongly agree (4). For the purpose of this statistical analysis, a dichotomous variable was constructed. Responses to items were collapsed into categories: "disagree" (strongly disagree and somewhat disagree) and "agree" (somewhat agree and strongly agree) [22]. The NEWS questionnaire has been shown to be reliable and valid in reflecting neighbourhood walkability and the perceived neighbourhood environment, across a broad range of countries and settings [23].



### 4.2.8 Statistical analysis

The starting sample comprised 1016 participants after merging IPAQ and NEWS data sets of whom 345 were excluded for unacceptable levels of missing data [24]. Therefore, the final analytic sample comprised 671 participants. We used SPSS® version 22 for Windows (IBM Corp: Armonk New York) for all data analyses. Descriptive statistics were computed to measure frequencies for all categorical variables. In order to test for the association between perceived built environment and physical activity, two models were constructed. Firstly, using an unadjusted logistic regression model, we tested the association between each perceived built environment item and the 3 physical activity outcomes. Then we used multivariable models, where all variables used in the first model were adjusted for gender and sex. In all regression models, all those who did not meet the 150 minutes per week recommended guidelines were used as the reference category. Statistical significance was set at $p < 0.05$.

## 4.3 Results

Table 4.1 shows the descriptive characteristics of the sample. The sample included more women than men (76% vs. 24%) with no significance difference between urban and rural areas (p=0.915). Over 34% of the subjects were aged 45-54 years, similarly in urban and rural areas (p=0.303). In all, 41.3% of the participants were married with significant urban vs. rural difference (36.6% vs. 44.9%, p=0.019). Over 54.4% were educated to a secondary school level and only 15.9% had skilled jobs and majority were black Africans (99.0%) from rural areas (56.8%), with no rural vs. urban differences in these characteristics (all p $\geq$0.130; Table 4.1).

Only 12.2% of respondents met recommended physical activity guidelines (≥150min/week) in the leisure-time domain. There was no difference in the prevalence of those persons accumulating at least 150min/week of moderate-to-vigorous activity in leisure time, between urban and rural settings (14.6% vs 9.8%, p=0.125). Overall, 57.0% of respondents did not accumulate at least 150 minutes per week of walking for leisure. This pattern was observed in both urban and rural settings (53.3% vs 57.8%), p=0.095). For transport-related physical activity, the proportion of respondents achieving at least 150 minutes per week was 11.7% in the overall sample, and 15.3% in urban and 8.6% in rural areas, respectively (p=0.018). Altogether, 68.9% of the respondents achieved the global recommendation of at least 150 minutes of moderate-to-vigorous physical activity per week (combining all domains). In fact, total moderate-to-vigorous activity prevalence was higher in the urban community (78.3%) compared to the rural sample (61.7%, p<0.001; Table 4.1).

Table 4.1 Descriptive characteristic of individuals by location

| Variables (N (%)) | Urban = 290 | Rural = 381 | p-value | All = 671 |
|---|---|---|---|---|
| **Covariates** | | | | |
| **Sex** | | | 0.915 | |
| Males | 69 (23.8) | 92 (24.1) | | 161 (24.0) |
| Females | 221 (76.2) | 289 (79.9) | | 510 (76.0) |
| **Age** | | | 0.303 | |
| 35-44 | 87 (30.0) | 134 (35.2) | | 221 (32.9) |
| 45-54 | 100 (34.5) | 129 (33.9) | | 229 (34.1) |
| 55 + | 103 (35.5) | 118 (31.0) | | 221 (32.9) |
| **Marital status** | | | **0.019** | |
| Single | 132 (45.5) | 133 (34.9) | | 265 (39.5) |
| Married | 106 (36.6) | 171 (44.9) | | 277 (41.3) |
| Divorce | 52 (17.9) | 77 (20.2) | | 129 (19.2) |
| **Education status** | | | 0.165 | |
| Primary | 86 (29.7) | 190 (49.9) | | 276 (41.1) |
| Secondary | 186 (64.1) | 179 (47.0) | | 365 (54.4) |
| Tertiary | 18 (6.2) | 12 (3.1) | | 30 (4.5) |
| **Occupation** | | | 0.558 | |
| Less skilled | 241 (83.1) | 323 (84.8) | | 564 (84.1) |
| Skilled | 49 (16.9) | 58 (15.2) | | 107 (15.9) |
| **Ethnicity** | | | 0.130 | |
| Black African | 285 (98.3) | 379 (99.5) | | 664 (99.0) |
| Colored | 5 (1.7) | 2 (0.5) | | 7 (1.0) |
| **Physical activity outcomes** | | | | |
| **Leisure-time physical activity*** | | | 0.125 | |
| <150min/week | 181 (85.4) | 194 (90.2) | | 375 (87.8) |
| ≥150min/week | 31 (14.6) | 21 (9.8) | | 52 (12.2) |
| **Walking for leisure*** | | | 0.095 | |
| <150min/week | 153 (53.3) | 226 (59.8) | | 379 (57.0) |
| ≥150min/week | 134 (46.7) | 152 (40.2) | | 286 (43.0) |
| **Transport-related physical activity*** | | | **0.018** | |
| <150min/week | 199 (84.7) | 255 (91.4) | | 454 (88.3) |
| ≥150min/week | 36 (15.3) | 24 (8.6) | | 60 (11.7) |
| **Total physical activity** | | | **<0.001** | |
| <150min/week | 63 (21.7) | 146 (38.3) | | 209 (31.1) |
| ≥150min/week | 227 (78.3) | 235 (61.7) | | 462 (68.9) |

*sub sample less than 671 due to missing variables; bold is significant p value

Table 4.2 illustrates the attributes of built environment overall and by location. The majority of respondents (68%) said they were able to do most of their shopping at a local store within walking distance from their homes. Destinations within neighborhoods were widely reported with more than 73% agreeing that there were many places to go within easy walking distance and 75% reporting that it was easy to walk to a transit stop from their residences. Approximately half the respondents (51%) felt that the distance between intersections was short, 54% agreed that there were many four-way intersections and 68% reported many alternative routes in their neighborhood. Despite over 54% agreeing that there were sidewalks on most streets, 52% reported sidewalks were not well maintained and not separated by grass from the streets. Almost half of the respondents interviewed indicated that there were no trees and a lack of pleasant scenery (interesting things) to see while walking and neighborhood was full of litter. Although 53% of the respondents reported a high volume of traffic along their streets, over 64% reported low volumes of traffic along nearby streets. Approximately half (51%) indicated that crosswalks did not help in crossing busy streets. The majority (57.1%) of the respondents reported that streets in their neighborhood were poorly lit at night, with 52% and 74% during the day/night respectively reporting that it was difficult to walk due to high crime rates (Table 4.2). In general, all built environment attributes were significantly different in urban and rural areas (all $p<0.001$; Table 4.2).

## Table 4.2 Descriptive characteristics of built environment attributes by location

| Variables (N (%)) | Urban = 290 | Rural = 381 | p-value | All = 671 |
|---|---|---|---|---|
| **Environmental attributes** | | | | |
| **Land use mix-access** | | | | |
| I can do most of my shopping at local stores | | | **<0.001** | |
| Agree | 243 (83.8) | 218 (57.2) | | 461 (68.7) |
| Disagree | 47 (16.2) | 163 (42.8) | | 210 (31.3) |
| Stores are within easy walking distance of my home | | | **<0.001** | |
| Agree | 243 (83.8) | 218 (57.2) | | 461 (68.7) |
| Disagree | 47 (16.2) | 163 (42.8) | | 210 (31.3) |
| There are many places to go within easy walking distance of my home | | | **<0.001** | |
| Agree | 258 (89.0) | 237 (62.2) | | 495 (73.8) |
| Disagree | 32 (11.0) | 144 (37.8) | | 176 (26.2) |
| It is easy to walk to a transit stop (bus, train) from my home | | | **<0.001** | |
| Agree | 258 (89.0) | 249 (65.4) | | 507 (75.6) |
| Disagree | 32 (11.0) | 132 (34.6) | | 164 (24.4) |
| **Street connectivity** | | | | |
| The distance between intersections in my neighbourhood is usually short | | | **<0.001** | |
| Agree | 238 (82.1) | 87 (22.8) | | 325 (48.4) |
| Disagree | 52 (17.9) | 294 (77.2) | | 346 (51.6) |
| There are many four-way intersections in my neighbourhood | | | **<0.001** | |
| Agree | 240 (82.8) | 125 (32.8) | | 365 (54.4) |
| Disagree | 50 (17.2) | 256 (67.2) | | 306 (45.6) |
| There are many alternative routes for getting from place to place in my neighbourhood | | | **<0.001** | |
| Agree | 248 (85.5) | 208 (54.6) | | 456 (68.0) |
| Disagree | 42 (14.5) | 173 (45.4) | | 215 (32.0) |
| **Places for walking and cycling** | | | | |
| There are sidewalks on most of the streets in my neighbourhood | | | **<0.001** | |
| Agree | 246 (84.8) | 118 (31.0) | | 364 (54.2) |
| Disagree | 44 (15.2) | 263 (69.0) | | 307 (45.8) |
| The sidewalks in my neighbourhood are well maintained | | | **<0.001** | |
| Agree | 224 (77.2) | 97 (25.5) | | 321 (47.8) |
| Disagree | 66 (22.8) | 284 (74.5) | | 350 (52.2) |
| There is a grass/dirt strip that separates the streets from the sidewalks in my neighbourhood | | | **<0.001** | |
| Agree | 199 (68.6) | 122 (32.0) | | 321 (47.8) |
| Disagree | 91 (31.4) | 259 (68.0) | | 350 (52.2) |
| **Neighbourhood surroundings** | | | | |
| Trees give shade for the sidewalks in my neighbourhood. | | | **<0.001** | |
| Agree | 198 (68.3) | 114 (29.9) | | 312 (46.6) |
| Disagree | 92 (31.7) | 267 (70.1) | | 359 (53.5) |
| There are many interesting things to look at while walking in my neighbourhood. | | | **<0.001** | |
| Agree | 210 (72.4) | 104 (27.3) | | 314 (46.8) |
| Disagree | 80 (27.6) | 277 (72.7) | | 357 (53.2) |
| My neighbourhood is generally free from litter. | | | **<0.001** | |
| Agree | 173 (59.7) | 107 (28.1) | | 280 (41.7) |
| Disagree | 117 (40.3) | 274 (71.9) | | 391 (58.3) |
| **Safety from traffic** | | | | |
| There is so much traffic along the street I live such that it makes it difficult to walk in my neighbourhood | | | **<0.001** | |
| Agree | 235 (81.0) | 127 (33.3) | | 362 (53.9) |
| Disagree | 55 (19.0) | 254 (66.7) | | 309 (46.1) |
| There is so much traffic along nearby streets that it makes it difficult to walk in my neighbourhood | | | **<0.001** | |
| Agree | 179 (61.7) | 61 (16.0) | | 240 (35.8) |
| Disagree | 111 (38.3) | 320 (84.0) | | 431 (64.2) |
| The crosswalks in my neighbourhood help walkers feel safe crossing busy streets | | | **<0.001** | |
| Agree | 228 (78.6) | 98 (25.7) | | 326 (48.6) |
| Disagree | 62 (21.4) | 283 (74.3) | | 345 (51.4) |
| **Safety from crime** | | | | |
| My neighbourhood streets are well lit at night | | | **<0.001** | |
| Agree | 234 (80.7) | 54 (14.2) | | 288 (42.9) |
| Disagree | 56 (19.3) | 327 (85.8) | | 383 (57.1) |
| The crime rate in my neighbourhood makes it unsafe to go on walks during the day | | | **<0.001** | |
| Agree | 22 (76.2) | 133 (34.9) | | 354 (52.8) |
| Disagree | 69 (23.8) | 248 (65.1) | | 317 (47.2) |
| The crime rate in my neighbourhood makes it unsafe to go on walks at night | | | **<0.001** | |
| Agree | 243 (83.8) | 257 (67.5) | | 500 (74.5) |
| Disagree | 47 (16.2) | 124 (32.5) | | 171 (25.5) |

Bold is significant p value

The univariable regression analyses in the overall sample are summarized in Table 4.3, showing some significant associations between built environment attributes and physical activity, but also a number of significant interactions, by setting, for those associations. In unadjusted regression analyses stratified by setting (Table 4.4), among urban dwellers who agreed that there were many four-way intersection, sidewalks were well maintained and separated from streets by grass and clean neighborhood were positively associated with leisure-time physical activity ( all $p<0.05$), Table 4.4. In addition, transit stop, four-way intersections, all infrastructure variables, pleasant scenery and well-lit streets at night were positively associated with walking for leisure (all $p<0.05$). This pattern was almost similar for total physical activity (Table 4.4). Meanwhile among rural counterparts, shade from trees and pleasant scenery were positively associated with leisure-time physical activity (both $p<0.05$). In addition, alternative routes and crosswalks were both associated with walking for leisure ($p<0.05$). Those who agreed that streets were well maintained and separated from street by grass were more likely to participate in transport related physical activity (both $p<0.05$), Table 4.4. Similarly, alternative routes in rural area were positively associated with total physical activity. Conversely, among urban respondents, high traffic volume and crime rate at night were inversely associated with walking for leisure (both $p<0.05$. Meanwhile in the rural area, high crime rate at night and traffic volume were negatively associated with leisure-time physical activity, walking for leisure and total physical activity (all $p<0.05$; Table 4.4), respectively.

**Table 4.3 Odd ratios and 95% confidence intervals from crude logistic regression between environmental factors and physical activity in the overall sample**

| Variables | LTPA | WL | TRPA | TPA | Setting * built environment factors: Setting*LTPA p | Setting *WL p | Setting *TRPA p | Setting *TPA p |
|---|---|---|---|---|---|---|---|---|
| **Built environmental factors (agree vs disagree)** | | | | | | | | |
| **Land use mix-access** | | | | | | | | |
| I can do most of my shopping at local stores | 1.70 (0.82-3.51) | 0.86 (0.61-1.22) | 0.85 (0.45-1.50) | 1.05 (0.74-1.49) | 0.053 | 0.807 | 0.755 | 0.942 |
| Stores are within easy walking distance of my home | 1.70 (0.82-3.51) | 0.86 (0.61-1.22) | 0.85 (0.45-1.50) | 1.05 (0.74-1.49) | 0.053 | 0.807 | 0.755 | 0.942 |
| There are many places to go within easy walking distance of my home | 1.21 (0.58-2.52) | 0.97 (0.68-1.40) | 0.96 (0.52-1.76) | 1.12 (0.78-1.62) | 0.536 | 0.736 | 0.891 | 0.149 |
| It is easy to walk to a transit stop (bus, train) from my home | **2.20*** (1.01-8.30) | **1.71**** (1.17-2.50) | **2.36*** (1.09-5.12) | **2.67***** (1.57-3.26) | 0.478 | 0.052 | 0.850 | 0.781 |
| **Street connectivity** | | | | | | | | |
| The distance between intersections in my neighborhood is usually short | 1.33 (0.73-2.40) | 1.23 (0.90-1.69) | **2.05*** (1.17-3.59) | **1.72**** (1.23-2.4) | 0.056 | 0.824 | 0.935 | 0.742 |
| There are many four-way intersections in my neighborhood | 1.10 (0.60-1.10) | 0.75 (0.54-1.03) | 0.84 (0.49-1.44) | 1.31 (0.95-1.82) | **0.018** | 0.185 | 0.421 | **0.007** |
| There are many alternative routes in my neighborhood | 1.91 (0.90-4.05) | 0.75 (0.54-1.06) | 1.11(0.61-2.01) | 1.07 (0.75-1.51) | 0.979 | 0.066 | 0.730 | **0.015** |
| **Infrastructure for walking and cycling** | | | | | | | | |
| There are sidewalks on most of the streets in my neighborhood | 1.31 (0.72-2.30) | **1.54**** (1.12-2.12) | 1.11 (0.65-1.92) | 1.10 (0.79-1.53) | 0.063 | **0.002** | 0.847 | **0.015** |
| The sidewalks in my neighborhood are well maintained | 1.31 (0.72-2.38) | 0.76 (0.55-1.04) | 0.98 (0.57-1.68) | 0.78 (0.56-1.08) | **0.004** | **<0.001** | **0.036** | **0.034** |
| There is a grass that separates the streets from the sidewalks | 1.56 (0.86-2.82) | **1.40*** (1.01-1.92) | 0.82 (0.48-1.41) | 1.09 (0.78-1.51) | **0.016** | **0.001** | 0.134 | **<0.001** |
| **Aesthetics** | | | | | | | | |
| Trees give shade for the sidewalks in my neighborhood. | 1.39 (0.77-2.49) | 0.96 (0.69-1.31) | 1.43 (0.83-2.46) | 1.33 (0.96-1.85) | **0.026** | 0.614 | 0.551 | 0.963 |
| There are many interesting things to look at while walking | 0.89 (0.50-1.60) | 0.83 (0.61-1.15) | **1.90*** (1.09-3.32) | **1.43*** (1.03-2.00) | **0.020** | 0.214 | 0.412 | 0.824 |
| My neighborhood is generally free from litter. | 0.94 (0.52-1.67) | **1.49*** (1.08-2.06) | 1.61 (0.94-2.76) | **1.38** (0.99-1.94) | **0.034** | 0.963 | 0.105 | 0.098 |
| **Safety from traffic** | | | | | | | | |
| Too much traffic along the street I live in makes it difficult walk | 0.66 (0.37-1.78) | **0.48***** (0.35-0.66) | 1.11 (0.64-1.92) | 0.98 (0.71-1.36) | 0.938 | 0.788 | 0.919 | 0.148 |
| Too much traffic along nearby streets makes it difficult walk | 0.77 (0.42-1.40) | 0.74 (0.53-1.04) | 1.10 (0.64-1.91) | 0.81 (0.58-1.45) | 0.180 | 0.726 | 0.762 | 0.497 |
| The crosswalks help walkers feel safe crossing busy streets | 1.14 (0.63-2.05) | 0.81(0.59-1.11) | 0.86 (0.50-1.47) | 1.31 (0.94-1.81) | 0.670 | 0.668 | 0.852 | 0.640 |
| **Safety from crime** | | | | | | | | |
| My neighborhood streets are well lit at night | 1.37 (0.76-2.46) | 1.75 (0.91-3.36) | **1.78*** (1.04-3.07) | **2.07***** (1.46-2.92) | 0.925 | **0.015** | 0.299 | 0.165 |
| The crime rate makes it unsafe to go on walks during the day | 0.75 (0.42-1.35) | 1.30 (0.68-2.49) | 0.75 (0.44-1.31) | 0.75 (0.54-1.04) | **0.015** | 0.391 | 0.248 | 0.596 |
| The crime rate makes it unsafe to go on walks at night. | 0.78 (0.37-1.61) | **0.41*** (0.18-0.90) | 0.60 (0.29-1.22) | 0.89 (0.61-1.30) | 0.967 | 0.308 | 0.678 | 0.086 |

*LTPA, Leisure time physical activity; WL, Walking for leisure; TRPA, Transport related physical activity; TPA, Total physical activity; P, p-value; OR, Odds ratios; CI Confidence interval;* *****p<0.05; ******p<0.01; *******p<0.001

Easy walk to a transit stop was significantly associated with transport-related physical activity (TRPA) (OR = 2.36, 95%-CI = 1.09-5.12; Table 4.4). Perceived short distances between intersections were also associated with transport-related physical activity (OR = 2.05, 95%-CI = 1.17-3.59; Table 4.4). The odds of reaching 150 minutes per week for transport-related physical activity was higher among those who reported pleasant scenery while walking. Well-lit street lights at night also made it more likely for a respondent to engage in transport-related physical activity (OR = 1.78, 95%-CI = 1.41-3.07; Table 4.4). Those who reported that the distance between intersections was short (OR = 3.78, 95%-CI = 1.34-10.65) and those who indicated the presence of many four-way intersections in their neighbourhood (OR = 4.32, 95%-CI = 1.68-1.11) were more likely to undertake transport-related physical activity (Table 4.4). Those who reported pleasant scenery (seeing interesting things) while walking were more likely to engage in transport-related physical activity (OR = 3.10, 95%-CI = 1.24-7.73; Table 4.4). The respondents who reported that crosswalks helped them to cross busy streets in the neighbourhood engaged more in transport related physical activity (OR = 3.88,95%-CI = 1.51-9.81; Table 4.4).

**Table 4.4 Odd ratios and 95% confidence intervals from crude logistic regression between environmental factors and physical activity (ref <150mins/week) in urban and rural participants**

| Variables | Urban | | | | Rural | | | |
|---|---|---|---|---|---|---|---|---|
| | LTPA | WL | TRPA | TPA | LTPA | WL | TRPA | TPA |
| **Environmental factors (agree vs disagree)** | | | | | | | | |
| **Land use mix-access** | | | | | | | | |
| I can do most of my shopping at local stores | **7.19** (0.95-54.55) | 1.37 (0.73-2.56) | 1.62 (0.70-3.75 | 1.43 (0.63-3.23) | 0.80 (0.32-2.00) | 1.24 (0.82-1.88) | 1.34 (0.58-3.10) | 1.34 (0.88-2.05) |
| Stores are within easy walking distance of my home | **7.19** (0.95-54.55) | 1.37 (0.73-2.56) | 1.62 (0.70-3.75 | 1.43 (0.63-3.23) | 0.80 (0.32-2.00) | 1.24 (0.82-1.88) | 1.34 (0.58-3.10) | 1.34 (0.88-2.05 |
| There are many places to go within easy walking distance of my home | 1.50 (0.33-6.86) | 1.34 (0.64-2.79) | 1.30 (0.46-3.68) | 0.68 (0.30-1.55) | 0.86 (0.34-2.17) | 1.16 (0.76-1.76) | 1.43 (0.61-3.31) | 1.34 (0.87-2.07) |
| It is easy to walk to a transit stop (bus, train) from my home | 1.70 (0.38-7.70) | 2.03**(1.19-2.81) | 2.22 (0.50-9.87) | 1.83** (1.19-2.81) | 3.66 (0.83-16.27) | 0.86 (0.41-1.80) | 1.87 (0.72-4.88) | **2.08** (0.94-4.54) |
| **Street connectivity** | | | | | | | | |
| The distance between intersections in my neighborhood is usually short | 2.88 (0.65-12.73) | 1.03 (0.56-1.88) | 1.71 (0.57-5.14) | 1.25 (0.62-2.53) | 0.43 (0.12-1.53) | 1.12 (0.69-1.83) | 1.61 (0.63-4.08) | 1.09 (0.66-1.79) |
| There are many four-way intersections in my neighborhood | 3.70* (1.05-12.99) | 2.17**(1.37-3.45) | 1.61 (0.67-3.87) | 1.57* (1.02-2.43) | 0.21 (0.03-1.59) | 1.29 (0.70-2.38) | 2.87 (0.95-8.65) | **0.52** (0.26-1.02) |
| There are many alternative routes in my neighborhood | 1.70 (0.38-7.70) | 0.92 (0.47-1.81) | 1.03 (0.37-2.87) | 0.56 (0.27-1.16) | 1.66 (0.64-4.30) | 1.94**(1.28-2.94) | 1.30 (0.56-3.00) | 1.59* (1.05-2.43) |
| **Infrastructure for walking and cycling** | | | | | | | | |
| There are sidewalks on most of the streets in my neighborhood | 4.15 (0.54-31.98) | 3.55***(2.15-5.88) | 1.68 (0.70-4.03) | 2.02** (1.30-3.15) | 0.42 (0.12-1.49) | 0.99 (0.52-1.90) | 1.90 (0.73-4.96) | 0.70 (0.34-1.45) |
| The sidewalks in my neighborhood are well maintained | 10.52* (1.40-79.31) | 3.41***(1.98-5.88) | 0.83 (0.36-1.94) | 3.31***(2.06-5.34) | 0.26 (0.06-1.15) | 0.76 (0.44-1.34) | 5.12* (1.18-22.30) | 1.33(0.66-2.67) |
| There is a grass that separates the streets from the sidewalks | 2.78* (1.02-7.58) | 2.63***(1.64-4.23) | 1.11 (0.52-2.35) | 2.51***(2.06-5.34) | 0.44 (0.14-1.35) | 0.82 (0.50-1.36) | 3.07* (1.02-9.25) | 0.62(0.35-1.11) |
| **Aesthetics** | | | | | | | | |
| Trees give shade for the sidewalks in my neighborhood. | 0.70 (0.30-1.66) | 1.22 (0.74-2.00) | 1.35 (0.62-2.96) | 1.00(0.55-1.82) | 3.95* (1.13-13.86) | 1.02 (0.65-1.60) | 0.93 (0.37-2.34) | 0.98(0.63-1.54) |
| There are many interesting things to look at while walking | 0.65 (0.25-1.67) | 1.75* (1.09-2.83) | 2.06 (0.81-5.20) | 1.04(0.56-1.95) | 5.24* (1.19-23.18) | 1.12 (0.67-1.88) | 1.20 (0.49-2.92) | 0.95(0.60-1.52) |
| My neighborhood is generally free from litter. | **2.33** (0.99-5.48) | 1.32 (0.82-2.12) | 2.04 (0.95-4.36) | 0.75(0.42-1.33) | 0.50 (0.16-1.55) | 1.34 (0.85-2.11) | 0.71 (0.26-1.97) | 1.40(0.88-2.24) |
| **Safety from traffic** | | | | | | | | |
| Too much traffic along the street I live in makes it difficult walk | 0.39* (0.16-0.95) | 0.39**(0.21-0.71) | 0.83 (0.35-1.96) | 1.01(0.49-2.05) | 0.42 (0.14-1.29) | 0.35***(0.22-0.56) | 0.78 (0.32-1.88) | 054**(0.35-.84) |
| Too much traffic along nearby streets makes it difficult walk | 0.76 (0.35-1.65) | 0.66 (0.41-1.06) | 0.74 (0.36-1.52) | 0.91(0.51-1.62) | 0.17 (0.22-1.31) | 0.57 (0.32-1.04) | 0.91 (0.30-2.79) | 0.69(0.40-1.20) |
| The crosswalks help walkers feel safe crossing busy streets | 1.26 (0.47-3.34) | 1.40 (0.80-2.46) | 1.86 (0.84-4.12 | 1.06(0.53-2.11) | 1.12 (0.41-3.03) | 1.65* (1.01-2.68) | 2.12 (0.70-6.42) | 1.29(0.81-2.06) |
| **Safety from crime** | | | | | | | | |
| My neighborhood streets are well lit at night | 1.01 (0.36-2.84) | 2.07* (1.16-3.70) | 0.95 (0.35-2.33) | **1.99***(1.04-3.80) | 0.94 (0.30-2.95) | 0.74 (0.41-1.34) | 1.97 (0.69-5.68) | 1.07(0.59-1.93) |
| The crime rate makes it unsafe to go on walks during the day | 1.34 (0.52-3.47) | 0.67 (0.39-1.15) | 0.72 (0.32-1.60) | 1.12(0.59-2.13) | 0.19**(0.05-0.66) | 0.90 (0.59-1.39) | **1.43 (0.61-3.35)** | 0.91(0.59-1.40) |
| The crime rate makes it unsafe to go on walks at night. | 0.85 (0.27-2.61) | 0.48* (0.25-0.92) | 0.78 (0.28-2.16) | 1.29(0.63-2.66) | 0.87 (0.32-2.36) | 0.72 (0.47-1.12) | 0.56 (0.21-1.60) | 0.61*(0.39-.96) |

*LTPA, Leisure time physical activity; WL, Walking for leisure; TRPA, Transport related physical activity; TPA, Total physical activity; OR, Odds ratios; CI Confidence interval;* *p<0.05; **p<0.01; ***p<0.001

The gender, age and site (and relevant interact terms in the overall sample) adjusted models are shown in Table 4.5 and 4.6. When these models where applied to overall sample, significant associations were apparent between proximity to local stores and leisure time physical activity (4.26; 1.00-18.08), proximity to transit stop and walking for leisure (2.44; 1.48-4.02), proximity to transit stop and total physical activity (2.12; 1.17-3.84), availability of four-way intersections and transport related physical activity (4.54; 1.54-13.43), interesting things and walking for leisure (1.93; 1.07-3.46), interesting things and transport related physical activity (3.84; 1.35-10.93), and too much traffic along the street and leisure time related physical activity (0.28; 0.09-0.89). These associations were found in both urban and rural areas, although not always of the same magnitude, and not always statistically significant in each setting (Table 4.6).

In the overall sample significant associations were also found between availability of sidewalks and walking for leisure (2.36; 1.25-4.44), availability of sidewalks and transport related physical activity (3.75; 1.06-13.27), availability of maintained sidewalks and total physical activity (4.69; 2.20-10.02), shaded (trees) sidewalks and walking for leisure (2.14; 1.19-3.85), too much traffic along the street and walking for leisure (2.17; 91.21-3.91), crosswalks and transport related physical activity (4.11; 1.47-11.50), and well light streets at night and walking for leisure (2.01; 1.04-3.89). When rural and urban settings were considered separately, these associations were not always in the same direction, not always significant, nor did that always result in significant interactions by setting (Table 4.6).



Finally, some significant associations were found in setting specific analyses, but not in the overall sample. These included the associations of leisure time physical activity with transit stops and crime rates in rural setting, the association of walking for leisure with availability of well-maintained sidewalks in urban setting, the associations of total physical activity with availability of four-way intersections, neighborhoods free from litter and well-lit streets at night in urban settings, and shaded sidewalks in rural setting (Table 4.6).

**Table 4.5 Odd ratios and 95% confidence intervals from adjusted logistic regression between environmental factors and physical activity in urban and rural participants in the overall sample**

| Variables[a] | Physical activity outcomes LTPA | WL | TRPA | TPA |
|---|---|---|---|---|
| **Environmental factors (agree vs disagree)** | | | | |
| **Land use mix-access** | | | | |
| I can do most of my shopping at local stores | **4.26*** (1.00-18.06) | 1.38 (0.76-2.51) | 0.87 (0.35-2.16) | 0.73(0.39-1.38) |
| There are many places to go within easy walking distance of my home | 0.46 (0.14-1.84) | 1.01 (0.54-1.90) | 0.81 (0.27-2.46) | 0.93 (0.46-1.87) |
| It is easy to walk to a transit stop (bus, train) from my home | 3.72 (0.85-16.28) | **2.44***** (1.48-4.02) | 2.58 (0.77-.8.66) | **2.12*(**1.17-3.84) |
| **Street connectivity** | | | | |
| The distance between intersections in my neighborhood is usually short | 1.01 (0.27-3.80) | 1.45 (0.75-2.80) | 3.53 (0.96-12.91) | 0.68 (0.34-1.38) |
| There are many four-way intersections in my neighborhood | 0.85 (0.22-3.21) | 0.59 (0.31-1.14) | **4.54**** (1.54-13.43) | 1.85 (0.93-3.65) |
| There are many alternative routes in my neighborhood | 2.37 (0.63-8.92) | 0.82 (0.48-1.40) | 1.35 (0.49-3.74) | 0.95 (0.51-1.76) |
| **Infrastructure for walking and cycling** | | | | |
| There are sidewalks on most of the streets in my neighborhood | 0.71 (0.17-2.89) | **2.36**** (1.25-4.44) | **3.75*** (1.06-13.27) | 1.13 (0.56-2.27) |
| The sidewalks in my neighborhood are well maintained | 0.52 (0.15-1.81) | 1.12 (0.55-2.27) | 0.58 (0.19-1.73) | **4.69***** (2.20-10.02) |
| There is a grass that separates the streets from the sidewalks | 1.85 (0.71-4.85) | 0.83 (0.45-1.54) | 0.96 (0.42-2.23) | 1.30 (0.74-2.28) |
| **Aesthetics** | | | | |
| Trees give shade for the sidewalks in my neighborhood. | 1.07 (0.37-3.05) | **2.14*** (1.19-3.85) | 1.02 (0.38-2.78) | 1.11 (0.59-2.09) |
| There are many interesting things to look at while walking | 0.72 (0.24-2.22) | **1.93*** (1.07-3.46) | **3.84*** (1.35-10.93) | 0.92 (0.49-1.73) |
| My neighborhood is generally free from litter. | 1.50 (0.65-3.45) | 1.34 (0.85-2.11) | 1.56 (0.75-3.23) | 1.04 (0.64-1.68) |
| **Safety from traffic** | | | | |
| Too much traffic along the street I live in makes it difficult walk | **0.28*** (0.09-0.89) | **2.17*** (1.21-3.91) | 0.76 (0.28-2.06) | 0.93 (0.50-1.74) |
| Too much traffic along nearby streets makes it difficult walk | 1.28 (0.46-3.58) | 1.05 (0.54-2.03) | 0.89 (0.36-2.23) | 0.90 (0.49-1.66) |
| The crosswalks help walkers feel safe crossing busy streets | 0.64 (0.20-1.98) | 0.73 (0.38-1.43) | **4.11**** (1.47-11.50) | 1.08 (0.56-2.07) |
| **Safety from crime** | | | | |
| My neighborhood streets are well lit at night | 0.70 (0.23-2.18) | **2.01*** (1.04-3.89) | 1.52 (0.43-5.38) | 2.50 (1.24-5.04) |
| The crime rate makes it unsafe to go on walks during the day | 0.44 (0.17-1.17) | 0.87 (0.49-1.52) | 0.89 (0.34-2.36) | 1.10 (0.61-1.99) |
| The crime rate makes it unsafe to go on walks at night. | 1.42 (0.46-4.41) | 0.91 (0.54-1.51) | 1.70 (0.57-5.04) | 0.83 (0.46-1.52 |

*LTPA, Leisure time physical activity; WL, Walking for leisure; TRPA, Transport related physical activity; TPA, Total physical activity;* [a] *adjusted for age, sex, site and the interaction term of site with each of the predictors of interest*; *****p<0.05; ******p<0.01; *******p<0.001

**Table 4. 6 Odd ratios and 95% confidence intervals from adjusted logistic regression between environmental factors and physical activity in urban and rural participants (ref <150mins/week)**

| Variables | Urban | | | | Rural | | | |
|---|---|---|---|---|---|---|---|---|
| | LTPA | WL | TRPA | TPA | LTPA | WL | TRPA | TPA |
| **Environmental factors (agree vs disagree)** | | | | | | | | |
| **Land use mix-access** | | | | | | | | |
| I can do most of my shopping at local stores | 6.76 (0.68-66.10) | 1.20 (0.35-4.07) | 0.38 (0.11-1.26) | 0.60 (0.15-2.41 | 4.18 (0.40-44.05) | 1.81 (0.64-5.18 | 0.86 (0.16-4.73) | 2.14 (0.69-6.65) |
| There are many places to go within easy walking distance of my home | 0.33 (0.03-3.46) | 0.51 (0.07-3.73) | 1.52 (0.23-9.97) | 1.75 (0.20-15.43) | 0.57 (0.08-3.98) | 0.73 (0.26-2.04) | 0.25 (0.05-1.26) | 0.57 (0.18-1.78) |
| It is easy to walk to a transit stop (bus, train) from my home | 1.21 (0.15-9.72) | 4.80***(2.08-11.12) | 1.41 (0.18-11.14) | 4.12 (0.52-32.79) | 9.78* (1.05-91.26) | 1.80 (0.30-10.77) | 2.12 (0.60-7.49) | 3.84** (1.75-8.46) |
| **Street connectivity** | | | | | | | | |
| The distance between intersections in my neighborhood is usually short | 1.86 (0.23-14.92) | 2.21 (0.60-8.10) | 8.10* (1.12-58.79) | 1.47 (0.23-9.25) | 2.40 (0.23-25.40) | 0.42 (0.11-1.59) | 3.61 (0.57-22.92) | 1.02 (0.32-3.27) |
| There are many four-way intersections in my neighborhood | 5.61 (0.42-9.02) | 0.88 (0.21-3.68) | 6.62*(1.42-30.82) | 16.57* (1.78-154.49) | 0.13 (0.01-2.25) | 1.27 (0.40-4.09) | 2.68 (0.41-17.39) | 2.17 (0.65-7.29) |
| There are many alternative routes in my neighborhood | 1.02 (0.12-9.02) | 0.76 (0.16-3.57) | 1.17 (0.24-5.75) | 0.34 (0.05-2.39) | 3.39 (0.65-16.62) | 0.75 (0.30-1.86) | 3.57 (0.95-13.38) | 1.10 (0.43-2.82) |
| **Infrastructure for walking and cycling** | | | | | | | | |
| There are sidewalks on most of the streets in my neighborhood | 2.19 (0.16-31.09) | 3.36* (1.07-10.51) | 0.25 (0.04-1.59) | 0.21 (0.03-1.72) | 1.26 (0.09-17.54) | 0.44 (0.09-2.21) | 1.36 (0.24-7.66) | 0.49 (0.19-1.25) |
| The sidewalks in my neighborhood are well maintained | 8.57 (0.56-30.08) | 8.06* (1.58-41.09) | 0.33 (0.07-1.64) | 4.49 (0.98-20.62) | 0.07 (0.00-6.66) | 0.67 (0.22-2.08) | 7.49 (0.36-154.60) | 0.92 (0.22-3.77) |
| There is a grass that separates the streets from the sidewalks | 2.27 (0.63-8.21) | 1.53 (0.59-3.97) | 0.64 (0.22-1.83) | 2.16 (0.75-6.23) | 4.16 (0.14-23.44 | 1.40 (0.39-5.04) | 0.70 (0.07-7.02) | 0.37 (0.08-1.60) |
| **Aesthetics** | | | | | | | | |
| Trees give shade for the sidewalks in my neighborhood. | 0.84 (0.20-3.61) | 0.96 (0.33-2.78) | 0.47 (0.12-1.91) | 0.96 (0.16-5.91) | 0.11 (0.01-1.49) | 2.94 (0.10-8.71) | 1.53 (0.29-7.10) | 3.05 (0.97-9.60) |
| There are many interesting things to look at while walking | 1.14 (0.24-5.51) | 3.38* (1.25-9.15) | 12.49** (2.04-76.43) | 0.85 (0.14-5.17) | 0.63 (0.05-8.83) | 30.74 (0.24-.29) | 3.97 (0.81-19.50) | 0.76 (0.22-2.63) |
| My neighborhood is generally free from litter. | 1.88 (0.56-6.30) | 1.15 (0.49-2.69) | 2.63 (0.88-7.87) | 4.01* (1.23-13.03) | 0.40 (0.05-3.02) | 1.71 (0.72-4.03) | 0.29 (0.05-1.67) | 0.70 (0.28-1.75) |
| **Safety from traffic** | | | | | | | | |
| Too much traffic along the street I live in makes it difficult walk | 0.19* (0.04-0.80) | 0.39 (0.12-1.29) | 0.81 (0.22-2.91) | 0.96 (0.20-4.66) | 0.19 (0.02-2.18) | 1.07 (0.37-3.09) | 1.39 (0.29-7.34) | 1.26 (0.42-3.81) |
| Too much traffic along nearby streets makes it difficult walk | 1.18 (0.31-4.41) | 0.59 (0.20-1.73) | 0.65 (0.21 (2.02) | 0.52 (0.15-1.84) | 0.44 (0.01-15.01) | 1.22 (0.31-4.73) | 0.51 (0.04-5.93) | 0.68 (0.19-2.42) |
| The crosswalks help walkers feel safe crossing busy streets | 0.65 (0.13-3.12) | 0.59 (0.19-1.85) | 2.97 (0.77-11.48) | 0.19 (0.03-1.14) | 24.41(0.75-94.15) | 0.76 (0.22-2.60) | 14.34* (1.23-67.56) | 0.95 (0.27-3.38) |
| **Safety from crime** | | | | | | | | |
| My neighborhood streets are well lit at night | 0.40 (0.08-1.99) | 10.26** (1.92-54.80) | 0.72 (0.12-4.31) | 8.58** (1.72-42.81) | 0.91 (0.11-7.62) | 0.66 (0.21-1.90) | 5.61 (0.64-49.36) | 2.31 (0.61-8.74) |
| The crime rate makes it unsafe to go on walks during the day | 0.82 (0.19-3.55) | 0.63 (0.21-2.49) | 0.39 (0.10-1.49) | 1.79 (0.50-6.40) | 0.04*(00.0-0.65) | 1.08 (0.41-2.85) | 2.07 (0.35-12.38) | 0.64 (0.25-1.68) |
| The crime rate makes it unsafe to go on walks at night. | 0.40 (0.07-2.46) | 0.63 (0.16-2.49) | 2.08 (0.40-10.89) | 0.51 (0.10-2.59) | 2.17 (0.39-11.96) | 0.69 (0.29-1.66) | 2.53 (0.58-11.16) | 0.84 (0.34-2.04) |

*LTPA, Leisure time physical activity; WL, Walking for leisure; TRPA, Transport related physical activity; TPA, Total physical activity;* [a]*adjusted for age and sex;* *p<0.05; **p<0.01; ***p<0.001

## 4.4 Discussion

A small proportion of subjects reached the 150-minutes per week threshold in all physical activity outcomes for transport- or leisure time-related physical activity. After adjusting for gender, age and site (including interaction terms), attributes of the built environment including proximity to local stores, transit stops, four-way intersections, the availability of sidewalks and crosswalks, shade from trees and pleasant scenery, as well as a high volume of traffic, well-lit streets at night and concerns of personal safety during the day were associated meeting physical activity guidelines of accumulating at least 150 minutes of moderate-to-vigorous activity per week, among the urban and rural South Africans surveyed.

This study supports the growing evidence that proximity and ease of access to destinations and services such as transit stops from residences are linked to more active living including: [25], leisure-time physical activity and walking for leisure activity. These findings corroborate the results from an 11 country, International Physical Activity and Environment Network study [26]. Similarly, a study in China found access to physical activity destinations was related to leisure-time physical activity [3]. Access to services has been associated with sufficient walking in some studies [27] but not all [28]. Although the current study did not ask the participants about ownership of cars, it is unlikely many people owned one, and thus walking, either for transport or leisure, is their only means of travel [29].



We found that the occurrence of short distances between intersections and 4-way intersections in the neighbourhood was significantly associated with respondents achieving 150 minutes or more of transport-related physical activity. This mirrors outcomes in most existing studies [6], with one exception [30]. However, the latter study was confined to the university environment and consequently perception of street connectivity may have been different from other studies [30]. Nevertheless, similar to other studies, the possible interpretation for a positive association would be that the availability of well-connected streets provides direct routes and safety for commuters, which ultimately increase the opportunity to walk and cycle for health. In a South African context, and particularly in urban areas where most of the streets are tarred and well connected, it facilitates residents' use of streets for transport-related physical activity.

Similar to previous studies [31], we also found that the presence of sidewalks on most streets was positively associated with walking for leisure. Likewise, better-quality sidewalks have been associated with both walking and meeting physical activity guidelines [32]. Here, neighbourhoods with sidewalks on most streets were also associated with meeting 150 minutes per week or more of moderate-vigorous-physical activity [33]. In another study, lack of sidewalks was inversely associated with walking for leisure [34]. A possible explanation for these inconsistencies is that in some cities, sidewalks may serve more as a barrier than they do as a facilitator for walking. Sidewalks can be of poor quality and badly maintained and when combined with overcrowding, a person's ability to use them and the enjoyment of doing so is reduced [34].



Our participants who indicated seeing many pleasant scenery while walking was more likely to reach 150 minutes per week or more of transport-related physical activity, similar to the results in another study [35]. This implies that the good quality aesthetics in the neighbourhood environment may positively influence transport-related physical activity.

This study also noted that high volumes of traffic along the streets was associated with a lower likelihood of meeting leisure-time physical activity and walking for leisure, which is similar to results found by studies in high-income countries [36]. For example, neighbourhoods in the USA that are safe from traffic were positively associated with walking [37]. Our results suggests that heavy traffic may be a barrier to physical activity and gives preliminary evidence of the need to provide safe traffic environments to support physical activity in Africa.

Concerning crosswalks, this study observed that individuals who agreed that the crosswalks in their neighbourhood helped walkers feel safe crossing busy streets were also more likely to report sufficient levels of transported-related physical activity. Again, these results are consistence with those found in other studies [38]. Hence, having crosswalks in neighbourhoods with high traffic volume may play an important role in determining the safety and physical activity levels of residents. The results of this study add to the existing, comparable literature by demonstrating that the association between crosswalks and physical activity meets public health recommendations for physical activity in urban and rural (African) settings.



Lack of streetlights at night and high crime during the day were inversely associated with walking for leisure and leisure-time physical activity, respectively. These findings are significant in a South African context where crime rates are considered to be very high, and increasing with rapid urbanization [39]. A study in the US found that feeling safe was linked to leisure time PA [38]. Similar results were reported in England [40] and Nigeria [11]. These demonstrate the need to assess perceived neighbourhood attributes and their influence on physical activity [41]. However, limited information in the African context makes direct comparisons with other studies challenging. Perceived safety during the day is related to walking as most individuals walk for transportation, especially among working class [11].

Regarding associations between walking for leisure and streetlights at night, our findings reflect the results from an Australian study [42]. Literature has associated street lights with physical activity [16], leisure-time physical activity [41] and transport related physical activity [43]. This relationship suggests that street lights could act as an indirect indicator for personal safety which in turn promotes walking for leisure as a choice rather than a need.

### 4.5 Limitations and strengths of the study

Our study has some limitations. It relies on self-reported physical activity and perceived environment, rather than objectively measured physical activity and perceived built environment. Recall bias and imprecise assessment of physical activity could dilute some of the observed associations. For instance, in Africa, illiteracy particularly in rural areas play a significant role in the accurate reporting of the time used for taking part in PA. In addition, we lack data on socioeconomic status, which may be a strong confounder of the associations between perceived environmental factors and transport related physical activity. Level of air pollution in urban areas resulting from heavy traffic could affect the health of pedestrians. Strengths of this study include that, as far as we are aware, it this is the first study of its kind to be conducted in South Africa. The study used both NEWS and IPAQ, which makes it comparable with studies globally. Furthermore, this study included a sample population from urban and rural areas that has geographical variability in a perceived built environment.

## 4.6 Conclusion

We found perceived built environment attributes to be associated with health-related physical activity. Our findings provide baseline evidence for the need to provide walkable environments that will make it easier for South African adults to meet physical activity guidelines.

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# Chapter 5

## Association between perceived built environment and prevalent hypertension among South African adults

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## Abstract

**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 Neighbourhood Environment Walkability Scale questionnaire. Prevalent hypertension was defined as previously diagnosed by a physician (self-reported diagnosed), screen-detected or the combination of both, 'any hypertension'. Logistic regressions were applied for analyses.

**Results:** In crude logistic regressions, self-reported hypertension was associated with land use mix-diversity (OR = 1.96, 95%CI = 1.51-3.34), street connectivity (OR = 0.53, 95%CI = 0.37-0.47), infrastructure for walking/cycling (OR = 0.65, 95%CI = 0.46-0.96), aesthetics (OR = 0.71, 95%CI = 0.51-0.90), traffic (OR = 1.46, 95%CI = 1.04-2.03) and crime (OR = 1.44, 95%CI = 1.03-2.02). In adjusted model, land use mix-diversity (OR = 2.37, 95%CI = 1.24-4.55) was significantly associated with self-reported hypertension. In similar multivariable models, the direction and magnitude of the effects was 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.



**Keywords:** hypertension, perceived built environment, risk factors, South Africa

## 5.1 Introduction

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 a greater than 50% increased prevalence expected from 2000-2025 [4]. According to van de Vijver et al [5], hypertension has been regarded as a disease of affluence but this has changed drastically in the last two decades with average blood pressures 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% [6].South Africa is experiencing a demographic and epidemiological transition with an increase in the population aged 50 years and older and rising prevalence of non-communicable diseases [7]. Hypertension is a common condition in South Africa and is a risk factor for heart attacks and stroke [8]. In 2000, high blood pressure was estimated to have caused 9% (n = 46 888) of all deaths and 2.4% (n = 390 860) of all disability-adjusted life years [9] among South Africans.



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 behaviour 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.

## 5.2 Methods

### 5.2.1 Study population

This cross-sectional study uses data from the 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 the participants were: (1) aged 35-70 years, (2) living within the identified neighbourhood and (3) no disability that precluded walking.



### 5.2.2 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**). All the participants signed a consent form.

### 5.2.3 Data collection

Participants were interviewed in the language of their choice. Structured, socio-demographic 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 neighbourhood environment.

### 5.2.4 Socio-demographic characteristics

Socio-demographic information on age, sex, marital status, education level, location and occupation were 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: skilled and less skilled. Smoking was defined as former smoker, current smoker and never smoked. In this analysis, former and current smoker were categorized as "yes" and never smoked to "no". Alcohol use was treated in the same way as smoking.



### 5.2.5 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 0-120 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 cutoff points for BMI were used to create the categories: underweight (< 18.5 kg/$m^2$), normal weight (18.5- < 25 kg/$m^2$), overweight (25-< 30 kg/$m^2$) and obese (> 30 kg/$m^2$).

### 5.2.6 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 ≥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.

### 5.2.7 Self-reported physical activity

The long version of the International Physical Activity Questionnaire (IPAQ), which is self-administered, was used to measure walking, 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 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].



### 5.2.8 Perceived built environment

The Neighbourhood Environment Walkability Scale (NEWS) questionnaire was used to obtain perceived neighbourhood attributes for each participant. Participants were instructed to consider neighbourhood 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) street 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 neighbourhoods*, *3-items*); f) safety from traffic (*traffic condition and its negative effect on environment, 3-items*); g) safety from crime (*perceived fear in the neighbourhood, 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 a more favourable 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-minutes 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 5.1. NEWS has been shown to be both a valid and reliable means of assessment [28].

**Table 5.1 Subscales and sample item description from the Neighbourhood Environment Walkability Scale**

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

### 5.2.9 Statistical analysis

The starting sample comprised 1016 participants of whom 345 were excluded for unacceptable missing data [29] after merging of three data sets. 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 socio-demographic 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 socio-demographic 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 socio-demographic (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'.



## 5.3 Results

### 5.3.1 General characteristics of the participants

Table 5.**2** depicts the overall socio-demographic characteristics, selected CVD risk factors and perceived built environment attributes of 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 (agreed) 24.0%, street connectivity (agreed) 56.0%, walking/cycling (agreed) 53.2%, aesthetics (agreed) 39.5%, safety from traffic (agreed) 49.2% and crime (agreed) 55.6%. These differences were not significant across gender (all $p > 0.05$), Table 5.2.

### 5.3.2 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 5.2. 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 5.2).

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 5.2.

**Table 5.2 Socio-demographic characteristics of participants**

| Variable | Female (n=510) Number (%) | Male (n=161) Number (%) | *p*-value | All (n=671) Number (%) |
|---|---|---|---|---|
| **Gender** | | | | |
| Female | | | | 510 (76.0) |
| Male | | | | 161 (24.0) |
| **Age** | | | 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) |
| **Marital status** | | | **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) |
| **Education status** | | | 0.109 | |
| Primary | 199 (39.0) | 77 (47.8) | | 276 (41.1) |
| Secondary | 289 (56.7) | 76 (47.2) | | 365 (54.4) |
| Tertiary | 22 (4.3) | 8 (5.0) | | 30 (4.5) |
| **Occupation** | | | 0.118 | |
| Skilled | 75 (14.7) | 129 (80.1) | | 564 (84.1) |
| Less skilled | 435 (85.3) | 32 (19.9) | | 107 (15.9) |
| **Ethnicity** | | | 0.240 | |
| African | 506 (99.2) | 158 (98.1) | | 664 (99.0) |
| Coloured | 4 (0.8) | 3 (1.9) | | 7 (1.0) |
| **Location** | | | 0.915 | |
| Urban | 221 (43.3) | 69 (42.9) | | 290 (43.2) |
| Rural | 289 (56.7) | 92 (57.1) | | 381 (56.8) |
| **Selected CVD risk factors** | | | | |
| **Blood pressure (M±SD)*** | | | | |
| 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) |
| **Self-reported reported hypertension** | | | **<0.001** | |
| No | 338 (66.3) | 134 (83.2) | | 472 (70.3) |
| Yes | 172 (33.7) | 27 (16.8) | | 199 (29.7) |
| **Screen-detected hypertension** | | | **<0.001** | |
| Normotension | 186 (55.0) | 38 (28.4) | | 224 (47.5) |
| Hypertension | 152 (45.0) | 96 (71.6) | | 248 (52.5) |
| **Any hypertension** | | | **0.003** | |
| No | 186 (36.5) | 38 (23.6) | | 224 (33.4) |
| Yes | 234 (63.5) | 123 (76.4) | | 447 (66.6) |
| **Self-reported reported diabetes** | | | 0.469 | |
| No | 466 (91.4) | 150 (93.2) | | 616 (91.8) |
| Yes | 44 (8.6) | 11 (6.8) | | 55 (8.2) |
| **BMI category** | | | **<0.001** | |
| Normal | 100 (19.6) | 107 (66.4) | | 207 (30.8) |
| Overweight | 127 (24.9) | 23 (14.3) | | 150 (22.4) |
| Obese | 283 (55.5) | 31 (19.3) | | 314 (46.8) |
| **Smoking** | | | **<0.001** | |
| No | 437 (85.7) | 70 (43.5) | | 507 (75.6) |
| Yes | 73 (14.3) | 91 (56.5) | | 164 (24.4) |
| **Alcohol use** | | | **<0.001** | |
| No | 448 (87.8) | 73 (45.3) | | 521 (77.6) |
| Yes | 62 (12.2) | 88 (54.7) | | 150 (22.4) |

SD; standard deviation, *sub-sample of 472 participants after excluding those with self-reported hypertension

**Table 5.2 continues**

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

### 5.3.3 Association between socio-demographic characteristics, CVD risk factors and self-reported hypertension

In general, univariate analysis indicated 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 5.3. Urban dwellers were at higher risk of hypertension (OR = 2.26, 95%CI = 1.61-3.16) compared to those in rural. 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 ($p > 0.05$).



### 5.3.4 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 neighbourhood destinations required walking more than 21 minutes (OR = 1.96, 95%CI = 1.51-3.34), Table 5.3. 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 neighbourhood 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 for 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).

### 5.3.5 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 5.3. 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, safety from traffic and crime were no longer significantly associated with the outcome (*p* > 0.05).

**Table 5.3 Correlates of self-reported hypertension**

| Variables | Univariable analysis | | | Multivariable analysis | | |
|---|---|---|---|---|---|---|
| | OR | 95%-CI | p-value | OR[c] | 95%-CI | p-value |
| **Gender** | | | | | | |
| Male (ref) | | | | | | |
| Female | **2.53** | 1.61-3.97 | **<0.001** | **2.43** | 1.41-4.17 | **<0.001** |
| **Age** | | | | | | |
| 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** |
| **Education level** | | | | | | |
| 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 |
| **Location** | | | | | | |
| Rural (ref) | | | | | | |
| Urban | **2.26** | 1.61-3.16 | **<0.001** | **1.74** | 1.03-2.92 | **0.038** |
| **BMI** | | | | | | |
| 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** |
| **Physical activity level** | | | | | | |
| <150min/week (ref) | | | | | | |
| >150min/week | 1.23 | 0.88-1.83 | 0.203 | 1.16 | 0.75-1.79 | 0.504 |
| **Land use mix- diversity** | | | | | | |
| ≤20 min (ref) | | | | | | |
| ≥21 min | **1.96** | 1.51-3.34 | **0.013** | **2.37** | 1.24-4.55 | **0.009** |
| **Land use mix-access** | | | | | | |
| Disagree (ref) | | | | | | |
| Agree | 1.31 | 0.88-1.96 | 0.182 | 0.79 | 0.43-1.44 | 0.436 |

| | | | | | | |
|---|---|---|---|---|---|---|
| **Street connectivity** | | | | | | |
| Disagree (ref) | | | | | | |
| Agree | **0.53** | 0.37-0.74 | <**0.001** | 0.64 | 0.35-1.17 | 0.149 |
| **Infrastructure for walking/cycling** | | | | | | |
| Disagree (ref) | | | | | | |
| Agree | **0.65** | 0.46-0.90 | **0.011** | 0.95 | 0.53-1.72 | 0.871 |
| **Aesthetics** | | | | | | |
| Disagree (ref) | | | | | | |
| Agree | **0.71** | 0.51-0.90 | **0.049** | 0.84 | 0.51-1.37 | 0.479 |
| **Lack of safety from traffic** | | | | | | |
| Disagree (ref) | | | | | | |
| Agree | **1.46** | 1.04-2.03 | **0.027** | 1.17 | 0.66-2.06 | 0.599 |
| **Lack of safety from crime** | | | | | | |
| 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; [c]odds ratios adjusted for age, gender, education, location, BMI and physical activity in the table; **bold** p = significant borderline

### 5.3.6 Multivariable associations of perceived built environment with screen-detected and any hypertension

The multivariable association of perceived built environment attributes with screen-detected hypertension and any hypertension are shown in Table 5.4. 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 ($p > 0.05$).

**Table 5.4 Multivariable associations of perceived built environment attribute with screen-detected and any hypertension**

| | Screen-detected hypertension | | | Any hypertension | | |
|---|---|---|---|---|---|---|
| **Variables** | **OR[a]** | **95%-CI** | **p-value** | **OR[c]** | **95%-CI** | **p-value** |
| **Gender** | | | | | | |
| Male (ref) | | | | | | |
| Female | **0.44** | 0.28-0.68 | **<0.001** | **0.47** | 0.29-0.78 | **0.004** |
| **Age** | | | | | | |
| 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** |
| **Education level** | | | | | | |
| 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 |
| **Location** | | | | | | |
| Rural (ref) | | | | | | |
| Urban | **2.41** | 1.37-4.24 | **0.002** | **2.70** | 1.64-4.47 | **<0.001** |
| **BMI** | | | | | | |
| 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 |
| **Physical activity level** | | | | | | |
| <150min/week (ref) | | | | | | |
| >150min/week | 0.91 | 0.58-1.43 | 0.691 | 0.99 | 0.66-1.47 | 0.942 |
| **Land use mix- diversity** | | | | | | |
| ≤20 min (ref) | | | | | | |
| ≥21 min | 2.13 | 0.95-4.75 | 0.065 | 1.26 | 0.67-2.39 | 0.476 |

| | | | | | | |
|---|---|---|---|---|---|---|
| **Land use mix-access** | | | | | | |
| Disagree (ref) | | | | | | |
| Agree | 0.98 | 0.55-1.73 | 0.930 | 1.02 | 0.61-1.72 | 0.928 |
| **Street connectivity** | | | | | | |
| Disagree (ref) | | | | | | |
| Agree | 0.55 | 0.30-1.01 | 0.053 | 0.72 | 0.42-1.23 | 0.226 |
| **Infrastructure for walking/cycling** | | | | | | |
| Disagree (ref) | | | | | | |
| Agree | 0.55 | 0.50-1.71 | 0.795 | 0.90 | 0.52-1.55 | 0.706 |
| **Aesthetics** | | | | | | |
| Disagree (ref) | | | | | | |
| Agree | 1.23 | 0.73-2.09 | 0.434 | 1.29 | 0.81-2.06 | 0.285 |
| **Lack of safety from traffic** | | | | | | |
| Disagree (ref) | | | | | | |
| Agree | **1.92** | 1.07-3.43 | **0.029** | 0.63 | 0.38-1.06 | 0.079 |
| **Lack of safety from crime** | | | | | | |
| 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; [c] Odds ratios adjusted for age, gender, education, location, BMI and physical activity in the table; **bold** p = significant borderline

## 5.4 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 neighbourhood 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, in turn lowering the risk of developing hypertension. In addition, we observed that street connectivity in the neighbourhood was associated with hypertension. However, there is very scant literature in this field. Nevertheless, 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, including social cohesion [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 a higher walkable environment was associated with a lower cardio-metabolic risk (CMR) among Australian adults. Their study revealed that a lower CMR score (including hypertension) was associated with higher walkable environment. Likewise, Li et al., [32] noted a lower in systolic and diastolic blood pressure for those living in high walkable neighbourhoods. In addition, 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 also less likely to be hypertensive, which may be 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 may lower prevalence hypertension risk by promoting walkability. One possible explanation, for instance, is that sidewalk buffers provide high walkable environments, which indirectly lowers cardio-metabolic risk factors such as hypertension. Therefore, individuals living in neighbourhoods with high street connectivity are more likely to meet recommended levels of walking, effective to lower blood pressure [35].

Perceived quality aesthetics in our study was also associated with lower prevalence of 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 neighbourhood 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]. In addition, other factors such as high walkable environment have been associated with better social cohesion, and better quality of life [41-44] and more likely to lower hypertension. Therefore, in the South African context, the population is more likely to walk in the neighbourhood that is perceive 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. Furthermore, in order to encourage walking, it's vital to create friendly environment, such as improved perceptions of safety, neighbourhood social cohesion and favourable aesthetics.

It is worth noting that in our crude logistic regression analysis, both safety from traffic and 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 that greater neighbourhood satisfaction related to an attenuation of the adverse link between higher perceived neighbourhood crime and higher systolic and diastolic blood pressure [45]. Other studies have linked with diastolic blood pressure in adolescents [46]. Likewise, fewer neighbourhood problems [47], greater safety [48] and favourable neighborhoods [49] were associated with blood pressure. According to Mujahid *et al.,* [48], potential hypertension-inducing features of neighbourhoods included limited access to resources conducive to healthy lifestyles and an excess of neighbourhood stressors. For example in Brazil, safety was also associated with being active in leisure time [50]. Likewise, in Nigeria perceived safety from crime and traffic were associated with walking [51] thus being insecure around your neighbourhood would limit your walkability which later leads to high risk of hypertension. In addition, other factors such as less stressful social environment associated with better quality of life [26] have been linked with low blood pressure.

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 [52] . One possible explanation apart from physical activity is that the availability of facilities within walkable distance provides access, for example, to unhealthy food. 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 and unhealthy food.

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 as well play a major role in determining hypertension prevalence among the participants in our study.

The study also identified that lack of safety from traffic in the neighbourhoods 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 neighbourhood was associated with a lower probability of hypertension [48]. In another meta-analysis, traffic volume on major roads within 100 m of the residence was associated with increased systolic and diastolic blood pressure [53]. 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. Furthermore, access to healthy food [54] and high socio-economic status [55] has been associated with lower hypertension. Future studies should consider investigating the mediating or moderating factors between safety from traffic and hypertension.

## 5.5 Limitations and strengths of the study



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 [56]. 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 non-participants with a different knowledge about hypertension and its correlates [57]. This was a cross-sectional design, which does not allow for causal relationships to be established. Some strengths of the current study are that this study used a sample that was selected to represent urban and rural communities in South Africa.

Furthermore, this study adds to a growing evidence base of scarce studies on the relationship between built environment and hypertension, particularly in African context.

## 5.6 Conclusion

In the current study, hypertension was highly prevalent. Overall, perceived built attributes were associated with prevalent hypertension. In the adjusted model, land use mix-diversity and lack of safety from traffic remained significantly associated with hypertension, suggesting that the relationship between the perceived neighbourhood built environment attributes and hypertension is not entirely dependent on physical activity, and that there are other influential factors, for example social cohesion or disorder. Furthermore, there is need to replicate similar studies using the recently - adapted NEWS instrument for the African urban context.

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# Chapter 6

## Does physical activity mediate the association between perceived neighbourhood aesthetics and overweight/obesity among South African adults living in selected urban and rural communities?

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## Abstract

**Background:** According to recent research studies in developed countries, perceived built environment attributes are associated with physical activity and obesity. However, there is limited data to understand the effect of physical activity on neighbourhood aesthetic and obesity. This study investigated the mediation effects of physical activity on the relationship between the perceived neighbourhood aesthetic environment and overweight/obesity in free-living South Africans.

**Methods:** A cross-sectional study of 671 adults aged ≥35 years was analysed. Physical activity was assessed using the validated International Physical Activity Questionnaire. Perceived neighbourhood aesthetics was assessed using the Neighborhood Environment Walkability Scale questionnaire.

**Results:** Of 671 participants, 76.0% were women, 34.1% aged 45-54 years, and 69.2% were overweight or obese. In adjusted logistic regression models, overweight/obesity was significantly associated with neighbourhood aesthetics (OR=0.68, 95%CI=0.50-0.93) and physical activity (OR=0.65, 95%CI=0.65-0.90). In expanded multivariable models, overweight/obesity was associated with age 45-55 years (OR=1.59, 95%CI=1.05-2.40), women (OR=6.24, 95%CI=3.95-9.86), tertiary education (OR=4.05, 95%CI=1.19-13.86) and urban residence (OR=2.46 95%CI=1.66-3.65). Aesthetics was positively associated with physical activity; both aesthetics and physical activity were negatively associated with overweight and obesity. There was no evidence to support a significant mediating effect of physical activity on the relationship between aesthetics and overweight/obesity.

**Conclusion:** Aesthetics and physical activity were significantly associated with overweight/obesity. Physical activity was not a strong mediator of the effects of perceived

aesthetics environment on overweight/obesity risk. Future studies should consider objective assessment of aesthetics and physical activity.

**Keywords:** Physical activity, body mass index, overweight/obesity, built environment, neighborhood environment, aesthetics, mediation analysis, South Africa, adults

## 6.1 Introduction

Overweight and obesity are a worldwide health problem, affecting populations across a diversity of social and income status. In 2014, the World Health Organization (WHO) reported that more than 1.9 billion adults were overweight and 600 million were obese [1]. Theoretically, walking could help preventing weight gain, however, the evidence about this effect is very controversial [2]. Furthermore, it is estimated that at least 2.8 million people die each year as a consequence of overweight or obesity worldwide [3]. South Africa is currently undergoing a rapid epidemiological transition and has the highest prevalence of obesity in sub-Saharan Africa (SSA) [4]. Recently, there has been a steep secular trend in obesity between 2003 and 2012, with the prevalence in women between the ages of 45-54 years increasing from 40% to more than 55% [5,6]. The etiology of obesity is multifactorial and involves complex interactions between the genetic make-up of the individual as well as social and environmental factors [7] Physical inactivity is one of the factors that has been studied extensively and has been shown to be associated with the prevalence of obesity [8].



The association between physical activity and neighbourhood environmental attributes, including aesthetics, along with health outcomes has furthermore been reported widely [9,10]. Fundamental characteristics of built environments and community design have been linked with overweight and obesity [11] in populations in transition, but have received relatively little attention in Africa [12]. Perceptions of aesthetic quality have in particular been linked to walking [13], a component of physical activity which is associated with overweight and obesity. A study in Asia found that those who regularly walked had high satisfaction with neighbourhood safety and had lower obesity risks [14]. Likewise, in USA aesthetic attributes were strongly associated with obesity [15]. The mediating effect of infrastructure for walking/cycling on physical activity and obesity has also been reported among American adults [16]. Moreover, in a recent study including urban South Africans, car owners spend less time in moderate-to-vigorous physical activity than those without access to private vehicles [17]. Therefore, in some cases, the impact of the perceived built environment on levels of physical activity may depend on the underlying reasons for physical activity, for example, leisure time compared to active travel or transport.

Few studies of the built environment and active living have adopted or tested a specific theoretical viewpoint, but the various capacities in which neighbourhood environments influence physical activity may be captured by Lynch's [18] theory of urban imageability. This theory suggests that an area is positively associated with the level of visitation or activity that occurs there. Imageability refers to the capacity of an area to stimulate memories among people who visit or live in that location. A neighbourhood's imageability, for example, may be influenced by its aesthetic appeal, either due to natural scenery or architecture, or by the presence of particular amenities, such as parks or local stores [18]. The theory suggests the reason why individuals living in areas perceived to have good quality aesthetics are more likely to be physically active and less likely to develop obesity.

To the authors' knowledge, little is known about the relationship between the physical activity, perceived aesthetic attributes and overweight and obesity among adults in South African community dwellers. According to Oyeyemi and colleagues,[12] there is a need to understand the environmental attributes associated with overweight and obesity among African adults, as this is critical to establish environmental interventions as a viable international strategy for activity-permissive environments and the primary prevention of obesity. Thus, the aim of this study was to investigate the association between physical activity, attributes of perceived neighbourhood aesthetic environment and overweight/obesity in free-living South African adults.

## 6.2 Methods

### 6.2.1 Study design and population

This cross-sectional study uses data from the Cape Town (urban) and Mount-Frere (rural) sites of the global Prospective Urban Rural Epidemiology (PURE) study [19]. During baseline evaluation conducted in 2008-2009, a random sample of adults was selected from well-established rural and urban formal settlements in South Africa. The inclusion criteria were the following: (1) households needed to have at least one member who was aged 35-70 years, (2) living within identified neighbourhood and (3) who did not have a disability that precluded walking. The study was conducted according to the Helsinki principles [20]. The Senate Higher Degrees Committee, Research Committees of the University of the Western Cape, South Africa and Population Health Research Institute (PHRI), Canada approved this study (Registration **#13/6/18**). All the participants signed a consent form.



### 6.2.2 Data collection

Participants were interviewed in the language of their choice. Structured, socio-demographic and lifestyle questionnaires were used. Physical examination included anthropometric measures [21]. A long version of International Physical Activity Questionnaire (IPAQ) was used to assess physical activity [22] and the Neighborhood Environment Walkability Scale (NEWS) questionnaire to assess perceived built environment [23].

### 6.2.3 Socio-demographic characteristics

Socio-demographic information on age, gender, marital status, education level, and occupation were elicited from participants. Participant's age was grouped into 4 categories: 35 to 44, 45 to 54, 55 to 64 and over 65 years. Marital status was classified as single, married, and divorced. Education level was classified as primary, secondary and tertiary education. Occupational status ranged from 1 to 11 different types of jobs prompted by the following statement; "*Please indicate which group best describes your main occupation*". In this study, the occupation status was then categorized as Skilled (technicians, machine operators, clerks, skilled agriculture and fishery workers) and less skilled (homemaker, service, shop and market workers).



### 6.2.4 Anthropometric measures

Body height and body weight was 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 0-120 kg. Body mass index (BMI) was calculated as weight (kg) divided by the square of the height ($m^2$). The WHO principal cutoff points for BMI [24] were used to create the categories: underweight (<18.5 kg/$m^2$), normal weight (18.5- < 25 kg/$m^2$), overweight (25-< 30 kg/$m^2$) and obese ($\geq$ 30 kg/$m^2$).

For the present analyses, participants were categorized based on their BMI as normal weight and overweight/obese using the 25 $Kg/m^2$ cutoff criterion.

### 6.2.5 Physical activity measure

The long version of the IPAQ was used to collect data on self-reported physical activity [22]. The IPAQ includes domains of work-related, transport, household and leisure activity for each category of walking, moderate and vigorous-intensity in terms of the frequency (days/week) and duration (min/day) in the last 7 days. The total number of weekly minutes of walking, moderate, and vigorous physical activity was computed according to World Health Organization, recommendations [25]. The sufficiently physically active group included participants in the moderate - or high intensity categories who met the WHO physical activity recommendation. According to the new WHO global standard, satisfying the recommendations for healthy physical activity was defined as engaging in at least 150 minutes of moderate-intensity activity per week, 75 minutes of vigorous-intensity activity per week, or an equivalent combination of moderate- and vigorous-intensity activity. For this analysis, physical activity was dichotomous variable representing meeting PA guidelines (physically active) and not meeting (physically inactive). The scoring protocol was followed for cleaning and truncation [26]. Acceptable reliability and validity of IPAQ has been reported elsewhere [27].



### 6.2.6 Perceived neighbourhood environment attributes measure

The subscale of NEWS survey questionnaire was used to obtain perceived aesthetic neighbourhood attributes for each participant. Participants were instructed to consider "neighbourhood" as the area within a 15–20 min walk from their home, and answered the following three questions: *"Trees give shade for the sidewalks in my neighbourhood", "There are many interesting things to look at while walking in my neighbourhood" and "My neighbourhood is generally free from litter"*. Test-retest reliability for these questions ranged from 0.79 to 0.94 [28]. These items were 4-point scale type responses ranging from 1 (strongly disagree) to 4 (strongly agree). For the purpose of statistical analysis, a dichotomous variable was constructed. Responses to items were collapsed into categories: "1 = disagree" (strongly disagree and somewhat disagree) and "2 = agree" (somewhat agree and strongly agree) [29]. The reliability and validity of the tool has been tested previously [30,31].

### 6.2.7 Statistical analysis

The starting sample comprised 1016 participants of whom 345 were excluded for unacceptable missing data [32]. This included 15 participants with missing data on gender, 40 participants younger than 35 years old, 18 underweight participants and 272 who did not have data on NEWS. Therefore, the final analytic sample comprised 671 participants. 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 characteristics by gender. Logistic regressions were used to investigate the determinants of overweight/obesity, always using normal body weight as a reference. In addition, we used logistic regressions to assess the association between perceived neighbourhood aesthetics and total physical activity. In order to identify factors associated with overweight/obesity, we fitted three models: Model 1 determined the association between aesthetics and overweight /obesity. Model 2 determined the association between aesthetics and overweight/obesity after adjusting for total physical activity. Finally model 3 included model 1 and 2 after adjusting for socio-demographic (sex, age and education status) variables. Crude and adjusted odd ratios (ORs) and 95% confidence intervals (CI) were calculated for perceived aesthetics, physical activity and socio-demographic characteristics variables. Statistical significance was set at $p < 0.05$.

### 6.2.8 Mediation analysis

We conducted mediation analyses to examine whether the relationship between perceived aesthetics and overweight/obesity was significantly mediated by physical activity. In these analyses, we assessed physical activity (mediator) as a categorical variable (inactive vs. active) perceived aesthetics as a categorical variable (disagree vs. agree) and adult overweight/obesity as categories (normal vs. overweight/obese). To examine the direct, indirect and total effects we used decomposition methodology procedures outlined by Buis [33]. This procedure was employed in the study because it allows computing of variables whose effects to be decomposed is a categorical variable. Further, this method reveals a mechanism through which one variable affects another variable [33]. The idea of this mechanism is illustrated in Figure **6.1**.



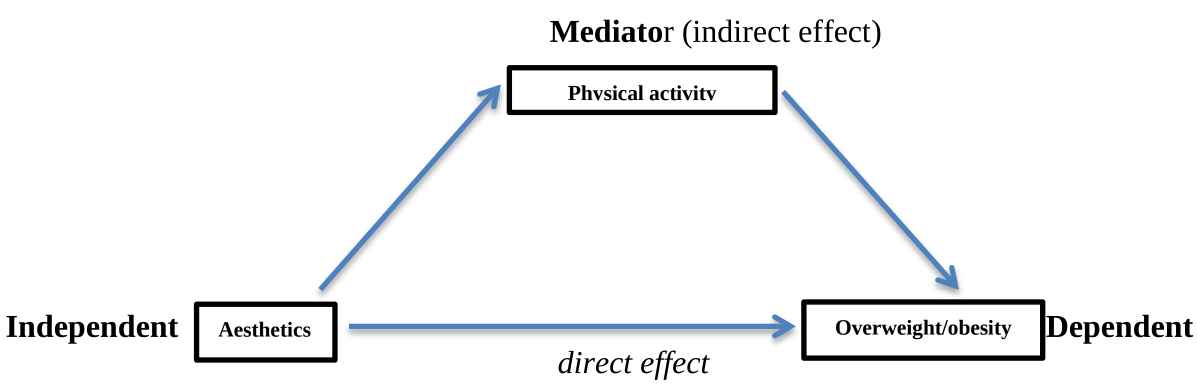


***Figure 6.1*** *The two possible causal paths to explain the association between aesthetic environment and overweight/obesity*

In this case, we applied the Buis procedure to a logit model in which the dependent variable was the log of overweight/obesity, the independent variable was aesthetic environment and the mediator variable was physical activity. The model also included gender, age, education and location as potential confounders. The model allowed us to decompose total association between aesthetics and overweight/obesity into two components: direct and indirect (mediated through physical activity) as shown in figure **6.1**. Equations obtained from Idecomp command applied to a logit model produced three coefficient estimates for aesthetics: coefficient for total effect (direct plus indirect paths); coefficient for the direct path and coefficient for the indirect path (mediated through physical activity). As we used a multiplicative model, it can be shown that coefficients (direct) X coefficients (indirect) = coefficients (total). It is also possible to use the original coefficients of the model to express the above decomposition in additive terms, to determine the percentage relative contribution of each path to the total association. Bootstrapping (1000 iterations) was used to obtain CIs for the estimated ORs. The Bui method was implemented with Idecomp package from SATA version 12. The probability criterion was set at $p < 0.05$.



## 6.3 Results

### 6.3.1 General characteristics of participants by gender

Table **6.1** shows the overall and socio-demographic characteristics of participants and by gender. A total of 671 participants comprising 76.0% women and 24.0% men, with 34.1% aged 45-54 years were included. Age distribution did not differ across gender ($p = 0.251$). The study population comprised 99.0% Africans and 1.0% mixed-ancestry participants, similarly by gender ($p = 0.240$). There were significant gender differences in the distribution of marital status, occupational status and BMI categories (all $p<0.001$). Overall, 69.2% of the participants were overweight and obese. With regard to physical activity, 68.9% of the participants were active and

31.1% were inactive. Physical inactivity was 30.8% in women and 32.3% in men (p = 0.718). Women (93.3%) were more inactive than men (88.8%) without gender difference (p = 0.062). Similarly, 60.5% of the participants perceived aesthetics as not good for walking according to the variables which are not specifically for walking. There was no gender difference for aesthetics (p = 0.082), Table **6.1.**

**Table 6.1 Descriptive characteristic of socio-demographic, physical activity, perceived aesthetics and overweight/obesity of the participants by gender**

| Variables | FEMALE | | MALE | | | All | |
|---|---|---|---|---|---|---|---|
| | n=510 | (%) | n=161 | (%) | p-value | n=671 | (%) |
| **Gender** | | | | | - | | |
| Women | 510 | 76.0 | - | - | | 510 | 76.0 |
| Men | - | - | 161 | 24.0 | | 161 | 24.0 |
| **Age** | | | | | 0.251 | | |
| 35-44 | 173 | 33.9 | 48 | 29.8 | | 221 | 33.0 |
| 45-54 | 166 | 32.5 | 63 | 39.1 | | 229 | 34.0 |
| 55-64 | 141 | 27.6 | 37 | 23.0 | | 178 | 27.0 |
| 65 and above | 30 | 6.0 | 13 | 8.1 | | 43 | 6.0 |
| **Education level** | | | | | 0.140 | | |
| Primary | 199 | 39.0 | 77 | 47.8 | | 276 | 41.1 |
| Secondary | 289 | 56.7 | 76 | 47.2 | | 365 | 54.4 |
| Tertiary | 22 | 4.3 | 8 | 5.0 | | 30 | 4.5 |
| **Marital status** | | | | | **0.001** | | |
| Single | 209 | 41.0 | 56 | 34.8 | | 265 | 39.5 |
| Married | 192 | 37.6 | 85 | 52.8 | | 277 | 41.3 |
| Divorced | 109 | 21.4 | 20 | 12.4 | | 129 | 19.2 |
| **Occupation** | | | | | **<0.001** | | |
| Skilled | 75 | 14.7 | 32 | 19.9 | | 107 | 15.9 |
| Less skilled | 435 | 85.3 | 129 | 80.1 | | 564 | 84.1 |
| **Ethnicity** | | | | | 0.240 | | |
| African | 506 | 99.2 | 158 | 98.1 | | 664 | 99.0 |
| Coloured | 4 | 0.8 | 3 | 1.9 | | 7 | 1.0 |
| **Location** | | | | | 0.915 | | |
| Urban | 221 | 43.3 | 69 | 42.9 | | 290 | 43.2 |
| Rural | 285 | 56.7 | 92 | 57.1 | | 381 | 56.8 |
| **BMI Categories** | | | | | **<0.001** | | |
| Normal | 100 | 19.6 | 107 | 66.4 | | 207 | 30.8 |
| Overweight/ Obese | 410 | 80.4 | 54 | 33.5 | | 464 | 69.2 |
| **Physical activity** | | | | | 0.718 | | |
| Inactive | 157 | 30.8 | 52 | 32.3 | | 309 | 31.1 |
| Active | 353 | 69.2 | 109 | 67.7 | | 462 | 68.9 |
| **Neighborhood Aesthetics** | | | | | 0.082 | | |
| Disagree | 318 | 62.4 | 88 | 54.7 | | 406 | 60.5 |
| Agree | 192 | 37.6 | 73 | 45.3 | | 265 | 39.5 |

-; not applicable

### 6.3.2 Socio-demographics and overweight/obesity

Table **6.2** shows the overweight/obesity patterns across socio-demographic characteristics levels. There was a significant association ($p < 0.001$) between gender and overweight/obesity. Women were more overweight and obese compared to men (55.4% vs. 19.4%, $p < 0.001$).

Overall 73.3% of participants with tertiary education were overweight/obese. Similarly, those with primary (39.3%) and secondary school education (45.8%) were overweight/obese ($p = 0.009$). Differences were also significant among woman ($p = 0.033$), but with marginal among men ($p = 0.054$).

### 6.3.3 Location and overweight/obesity

59.7% of participants in urban and 37.0% in rural areas were overweight and obese. These differences between genders were significant ($p < 0.001$).



### 6.3.4 Association between perceived neighbourhood aesthetics and total physical activity

A univariate model (table not shown) of an association between aesthetics and physical activity shows that participants who agreed that the perceived aesthetic of the environment was good were (OR=1.59, 95%-CI=1.23-2.24) more likely to be active.

## Table 6.2 Socio-demographic characteristics of participants by overweight/obesity and gender

| Variables | Female (n=510) | | | Male (n=161) | | | All (n=671) | | |
|---|---|---|---|---|---|---|---|---|---|
| | BMI Categories (n (%)) | | | BMI Categories (n (%)) | | | BMI Categories (n (%)) | | |
| | **Normal** | **Overweight/obese** | **p-value** | **Normal** | **Overweight/obese** | **p-value** | **Normal** | **Overweight/obese** | **P-value** |
| **Gender** | | | | | | | | | **<0.001** |
| Women | | | | | | | 299 (44.6) | 372 (55.4) | |
| Men | | | | | | | 541 (80.6) | 130 (19.4) | |
| **AGE** | | | 0.111 | | | 0.664 | | | 0.307 |
| 35-44 | 262 (51.4) | 248 (48.6) | | 134 (83.2) | 27 (16.8) | | 392 (58.4) | 279 (41.6) | |
| 45-54 | 197 (38.6) | 313 (61.4) | | 133 (82.6) | 28 (17.4) | | 340 (50.7) | 331 (49.3) | |
| 55-64 | 224 (44.0) | 286 (56.0) | | 126 (78.3) | 35 (21.7) | | 343 (51.1) | 328 (48.9) | |
| 65 and above | 204 (40.0) | 306 (60.0) | | 111 (68.9 | 50 (31.1) | | 327 (48.8) | 344 (51.2) | |
| **Education level** | | | **0.033** | | | 0.054 | | | **0.009** |
| Primary | 270 (52.9) | 240 (47.1) | | 117 (72.7) | 44 (27.3) | | 407 (60.7) | 264 (39.3) | |
| Secondary | 232 (45.5) | 278 (54.5) | | 134 (83.2) | 27 (16.8) | | 364 (54.2) | 307 (45.8) | |
| Tertiary | 93 (18.2) | 417 (81.8) | | 81 (50.3) | 80 (49.7) | | 179 (26.7) | 492 (73.3) | |
| **Marital status** | | | 0.586 | | | 0.266 | | | 0.236 |
| Single | 237 (46.5) | 273 (53.5) | | 141 (87.6) | 20 (12.4) | | 370 (55.1) | 301 (44.9) | |
| Married | 228 (44.7) | 282 (53.3) | | 123 (76.4) | 38 (23.6) | | 366 (54.5) | 305 (45.5) | |
| Divorced | 206 (40.4) | 304 (59.6) | | 129 (80.1) | 32 (19.9) | | 312 (46.5) | 359 (53.5) | |
| **Occupation** | | | 0.270 | | | 0.155 | | | 0.298 |
| Skilled | 197 (38.7) | 313 (61.3) | | 133 (82.6) | 28 (17.4) | | 363 (54.1) | 308 (45.9) | |
| Less skilled | 232 (45.5) | 278 (54.5) | | 166 (72.0) | 45 (28.0) | | 326 (48.6) | 345 (51.4) | |
| **Location** | | | **<0.001** | | | **<0.001** | | | **<0.001** |
| Urban | 166 (32.5) | 344 (67.4) | | 105 (65.2) | 56 (34.8) | | 270 (40.3) | 401 (59.7) | |
| Rural | 273 (53.5) | 237 (46.5) | | 149 (92.5) | 12 (7.5) | | 423 (63.0) | 248 (37.0) | |

### 6.3.5 Association between total physical activity, aesthetics and overweight/obesity

Table **6.3** shows three models. Model 1 is an association between aesthetics and overweight/obesity. Model 2 illustrates an association between physical activity and overweight/obesity after adjusting for aesthetics. Model 3 includes model 1 and 2 after adjusting for socio-demographic variables. In Model 1, the crude analysis showed that those who perceived their aesthetics to be of good quality were less likely to be overweight/obese (OR = 0.65, 95%CI = 0.48-0.89). In model 2 after introduction of total physical activity, both aesthetics (OR = 0.68, 95%CI = 0.50-0.93) and total physical activity (OR = 0.65, 95%CI = 0.62-0.90) were associated with overweight/obesity. However, in model 3 after introduction of socio-demographic variables, the significance of both perceived aesthetics and total physical activity was lost ($p > 0.05$). This shows that aesthetics and total physical activity are not significant risk factors of overweight/obesity after controlling the effect of other variables.

**Table 6.3 Multivariable model testing the association of physical activity on aesthetics and overweight/obesity (n=671)**

| Variables | Model 1 | | Model 2 | | Model 3 | |
|---|---|---|---|---|---|---|
| | Overweight/obesity | | Overweight/obesity | | Overweight/obesity | |
| | OR | 95%-CI | OR | 95%-CI | OR | 95%-CI |
| **Aesthetics** | | | | | | |
| disagree (ref) | | | | | | |
| Agree | **0.65**** | 0.48-0.89 | **0.68*** | 0.50-0.93 | 0.94 | 0.63-1.40 |
| **Physical activity** | | | | | | |
| inactive (ref | | | | | | |
| Active | - | - | **0.65*** | 0.62-0.90 | 0.71 | 0.49-1.03 |
| **Gender** | | | | | | |
| Men (ref) | | | | | | |
| Women | - | - | - | - | **6.24***** | 3.95-9.86 |
| **Age** | | | | | | |
| 35-44 (ref) | | | | | | |
| 45-54 | | | | | **1.59*** | 1.05-2.40 |
| 55-64 | | | | | 1.40 | 0.91-2.16 |
| 65 and above | | | | | 1.64 | 0.79-3.41 |
| **Education level** | | | | | | |
| primary (ref) | | | | | | |
| Secondary | - | - | - | - | 1.12 | 0.47-2.68 |
| Tertiary | - | - | - | - | **4.05*** | 1.19-13.86 |
| **Location** | | | | | | |
| rural (ref) | | | | | | |
| Urban | - | - | - | - | **2.46***** | 1.66-3.65 |

Model 1 (univariate analysis for aesthetics and overweight/obesity)
Model 2 (aesthetics and overweight/obesity after adjusting for physical activity)
Model 3 (adjusted for aesthetics, physical activity, gender, age, education and location)
OR, odds ratios; CI, confidence interval
*p<0.05; **p<0.01; ***p<0.001
- Not applicable

### 6.3.6 Mediation model

Table **6.4** shows mediation effect of physical activity on the relationship between perceived neighbourhood aesthetics and overweight/obesity. In model 1, the direct (aesthetics) and indirect (physical activity) effects on overweight/obesity were both significant ($p = 0.05$). While, aesthetics accounted only 8.8% ($p = 0.044$) of the effects, physical activity accounted for 91.2% ($p = 0.004$). In model 2 after adjusting for all variables (physical activity, gender, age, education and location), aesthetics (direct) accounted for 39.6% ($p = 0.035$) of the effects. Physical activity (indirect) did not show significant mediating effect ($p = 0.135$) on the association.

**Table 6.4 Mediation effect of physical activity on the relationship between aesthetics and overweight/obesity**

| | Variables | β | Std. Err. | % of effects | p>z | 95%, | CI |
|---|---|---|---|---|---|---|---|
| **Model 1** | | | | | | | |
| | Total | -0.475 | 0.149 | 100.0 | **0.001** | -0.767 | -0.183 |
| | Indirect (physical activity) | -0.042 | 0.021 | 8.8 | **0.044** | -0.082 | -0.001 |
| | Direct (aesthetics) | -0.433 | 0.150 | 91.2 | **0.004** | -0.727 | -0.139 |
| **Model 2** | | | | | | | |
| | Total | -0.475 | 0.205 | 100.0 | **0.021** | -0.877 | -0.073 |
| | Indirect (physical activity)* | -0.287 | 0.192 | 60.4 | 0.135 | -0.662 | 0.089 |
| | Direct (aesthetics) | -0.188 | 0.089 | 39.6 | **0.035** | -0.363 | -0.013 |

***β,*** *beta coefficient; odds ratios; CI; confidences interval; p-value* ***bold****; significant;* *******physical activity, gender, age, education, location*

## 6.4 Discussion

To our knowledge, this is the first epidemiological study to examine the mediating effect of physical activity on the relationship between perceived neighbourhood aesthetics and overweight and obesity, in urban and rural settings, in free-living adults South Africans. The major findings were that the perception of neighbourhood aesthetics was positively associated with physical activity. Aesthetics and physical activity in univariate analyses were also associated with overweight and obesity. However, there was no significant mediating effect of physical activity on the relationship between aesthetics and overweight/obesity risk.

In our current study for those who were active, the odds of being overweight and obese were 35% lower. Similar results have been reported in African countries [34,35], middle-income countries [36] and high-income countries [37]. Our study is in line with the current WHO recommendation to accumulate at least 30 minutes of moderate-to-vigorous physical activity (PA) on five or more days of the week [36], which in turn lowers risks for overweight or obesity. For this reason, promoting PA among adults remains a good strategy to reduce morbidity and mortality due to overweight/obesity.



In our univariate analysis, the perceived quality of neighbourhood aesthetics was associated with a lower risk for overweight or obesity. This implies that neighbourhood aesthetics have significant associations with overweight and obesity among adult South Africans in selected locations. In addition, it highlights that the availability of pleasing or natural environmental factors with perceived positive aesthetic qualities within walking distance can positively impact on energy expenditure which may assist in overweight and obesity control. This is in line with other research, where perceived neighbourhood aesthetics quality was associated with physical activity [38]. Because the aesthetic neighbourhood environment affects many individuals, urban upgrade and renewal projects may have a significant impact on physical activity levels at the population. It has therefore been postulated that ensuring good aesthetic quality of the neighbourhood may be a practical and effective policy for encouraging physical activity and reducing overweight and obesity in African adults. However, this relationship may be confounded by socio-economic status, age, urbanization and sex, as the relationship in model 3 is only an indirect one, and physical activity does not contribute significantly to the final model.

Furthermore, our mediation analysis provides only partial support for the conceptual model and suggests that while adults' perceptions of neighbourhood aesthetics are significantly related to overweight and obesity, physical activity is not a significant mediator of this relationship in our settings. Our findings are in agreement with some existing studies [39] but not all [40]. One possible explanation of the variation in findings would be that some studies have been conducted in developed countries, urban cities than rural settings which have different quality of aesthetics. Thus, individuals in the rural areas may tend to engage in more physical activity compared to their urban-dwelling counterparts, most of which is not volitional or related to leisure-time activity. Another related factor would be that most of the individuals, for example in rural areas, live relatively far away from facilities/services and few own cars. For this reason individuals are forced to either walk or cycle for a purpose such as transport. Physical activity in some cases, in particular those related to transport may not be volitional and therefore, for this type of activity, the perception of aesthetics would not impact on physical activity.

The current study did not include measures of the food environment and eating habits, which may be important in explaining obesity. However, factors such as perceived availability of healthy food [41], supermarkets [42] and neighbourhood social environment [43], have been related as independent contributors of overweight/obesity risk. As a result, the availability of such facilities in the neighbourhood makes for greater access and may stimulate interest in changing habits relating to health and wellbeing among the participants.

## 6.5 Limitations and strengths

Our study had some limitations that need to be highlighted. We only used perceived aesthetics to measure built environment, thus, it is not clear whether these perceptions accurately reflect the objective neighbourhood. For this reason, future studies should consider evaluating other built environmental attributes. We assessed PA by self-report data which may not be as precise as objective methods such as accelerometers. Thus, PA prevalence in this study could be overestimated. The other concern is the "global" PA as a mediator. The relationship between environment and PA is domain specific, and perhaps less likely to find any relationship between aesthetics and other PA activity, such as domestic. Sub-analyses with reduced sample size due to missing data lacked sufficient power to uncover all significant associations. Finally, the cross-sectional design of the study makes it difficult determine the causal direction of the relationship. However, the study used a sample that was selected to represent urban and rural communities in South Africa.

## 6.6 Conclusion

The observed prevalence overweight/obesity was high. Aesthetics and physical activity were significantly associated with overweight/obesity. However, physical activity was not a strong mediator variable between perceived aesthetics and overweight/obesity. Future studies should consider objective assessment of neighbourhood aesthetics and physical activity, particularly in urban-dwelling South Africans. In addition, future studies should consider using longitudinal design to evaluate food related environments, which are related to overweight or obesity.

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# Chapter 7

## The relationship between objectively-measured attributes of the built environment and selected cardiovascular risk factors in a South African urban setting

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## Abstract

**Introduction:** Evidence concerning the relationship between objectively-measured physical activity, attributes of the built environment (BE), and cardio-metabolic risk in populations from lower- and middle-income countries is lacking. In this paper, we describe the association between the objectively-measured BE with body mass index (BMI), blood pressure (BP) and physical activity (PA), in adult South Africans.

**Methods:** This cross-sectional study included 341 adults aged ≥35 years drawn from the Prospective Urban Rural Epidemiology cohort study. Actigraph GT3X accelerometer data and Geographic Information Systems (GIS) were used to objectively measure PA and BE attributes.

**Results:** In age and sex adjusted models, access to community centres (1000 m) was positively related to BMI (β = 4.79, 95%CI: 2.06 to 7.34) and diastolic BP (β = 4.97, -0.00 to 9.95; $p$ = 0.050). Distance from a community centre (1600 m) was positively related to diastolic BP (β = 6.58, 1.57-11.58; $p$ = 0.010) and inversely with moderate-to-vigorous physical activity (β = -60.9, -134.9 to -3.7; $p$ = 0.039). Distance to a shopping centre (1000 m and 1600 m) were positively related to BMI (β = 4.78, 1.11-8.45; $p$ = 0.011) and systolic BP (β = 6.99, 0.03-13.95; $p$ = 0.049).

**Conclusion:** Objectively-measured BE walkability was significantly associated with BMI, systolic, diastolic blood pressure and moderate-to-vigorous physical activity. Future research should include multiple aspects of built environment variables in order to provide for a broader understanding of their effect on cardiovascular risk profile of African populations.

**Key words** - Built environment, walkability, physical activity, Geographic Information System, accelerometer, objective measurement, body mass index, blood pressure, risk factors, South Africa

## 7.1 Introduction

Non-communicable diseases, such as cardiovascular disease (CVD), are the leading cause of death in high income and many low- and middle income countries (LMICs) [1], including South Africa [2]. Rises in CVDs diagnoses are attributable to obesity, high blood pressure and physical inactivity [3] compounded by a change in lifestyle behaviours [4]. These rising figures of CVDs are of concern in South Africa and other countries in the region [5].

Rapid epidemiological shifts in population health and disease burden have been linked to changes in the (BE) that may promote or adversely affect active transport, such as walking to and from places, because this has been associated with reduced risk of obesity, and non-communicable diseases (NCDs) [6-8]. Yet, there is little empirical evidence that has used objectively-measured attributes of the BE with selected CVD risk factors including PA in an urban African context. The majority of studies concerning objective and subjective measures of the BE, including attributes of walkability such as land-use mix or proximity to various community facilities or destinations, have been undertaken in developed or high-income countries [9, 10, 11], where the context, culture and perceptions regarding access may be specific [12]. At least one study in a middle-income country has linked aspects of the neighbourhood and built environment such as: water supply, garbage collection and street lighting to health status in older adults, [13]. Nevertheless, both objective and subjective studies incorporating measures of the BE are sparse [14] and those studies that have used them have shown mixed results in both low-income [15] and high-income countries [16].

Built environments that support utilitarian walking, with destinations in close proximity, have been linked to lower BMI [17], BP [18] and more walking for transport [19]. Other studies have associated a walkable environment with walking, bicycling, using public transit, and a decreased likelihood for driving or owning a car [20]. Studies have also linked a high density of fast-food outlets vs full-service and non-chain restaurants in a neighbourhood environment, with higher and lower BMI, respectively [21], with other studies in this field yielding mixed results [22].

Given that cardiovascular disease in South Africa and Africa at large is increasing [5], developing and implementing built environment strategies that promote physical activity and thus reduce CVD risk, requires input from context-specific studies. Therefore, the aim of this study was to evaluate the relationship between objectively-measured built environmental attributes with BMI, systolic BP (SBP), diastolic BP (DBP) and physical activity in adult South Africans.



## 7.2 Methods

### 7.2.1 Study setting and population

Participants in the current study were drawn from the Langa Township site of the Prospective Urban Rural Epidemiology (PURE) cohort study in Cape Town, South Africa. The cohort, established in 2009, included 2064 Black South African men and women aged 35-70 years. In this study, all PURE participants were invited to take part in the study during 2014-2015 follow up phase. Inclusion criteria were: (1) be aged 35–70 years, (2) be living within identified household, and (3) have no disability that precluded walking.

### 7.2.2 Study design and sample size

This was a cross-sectional survey nested within PURE follow-up evaluation conducted in 2013. A sample of 459 participants was recruited to take part in the current study. However, only a representative sample of 341 individuals, both men and women, who were drawn from PURE cohort study, provided complete data on Geographic Information System (GIS) and accelerometer, respectively**.**

### 7.2.3 Ethical considerations

The study was conducted in accordance with the principles of the Helsinki declaration [23]. All participants provided signed informed consent prior to participating in the study, which was approved by the Senate Higher Degrees committee and Research Committees of the University of the Western Cape, South Africa (Registration **#13/6/18**).



### 7.2.4 Data collection procedure

The data collection followed baseline procedures developed in 2009. Participants were interviewed in the language of their choice. For anthropometrics, participants were invited to a convenient centre (e.g. the community school premises or church) where trained research assistants carried out all physical measurements and introduced accelerometers. A dedicated research assistant instructed and demonstrated how to wear the monitor above the right hip during all waking hours for seven consecutive days, except during water activities and showering. All protocol and standard guidelines were followed during the initializing period of the accelerometers [24]. Socio-demographic characteristics included age, gender, marital status, education level, employment status, family income, smoking, alcohol use and ownership of motor cars in the household.

### 7.2.5 Anthropometric measures

Height to the nearest 0.1 cm was measured using a portable stadiometer with participant standing in bare feet and upright. Weight to the nearest kilogram, was measured using a portable bathroom weighing scale (Soehnle, Germany), with participants lightly dressed. BMI was calculated as weight (kg) divided by height ($m^2$). Waist circumference (WC) was measured, halfway between the lower costal margin and the iliac crest. Hip circumference was measured at the widest point over the buttocks. For each of waist and hip circumference, two measurements to the nearest 0.5 cm were recorded. If the variation between the measurements was greater than 2 cm, a third measurement was taken. The mean of the two closest measurements was calculated. Waist hip ratio (WHR) was obtained by dividing the mean waist circumference by the mean hip-circumference.



### 7.2.6 Blood pressure measurement and definition of hypertension

Trained staff measured blood pressure (BP) using an Omron 711 (IT; Omron Healthcare Europe BV, Hoofddorp, The Netherlands) automated device with the appropriate cuff size for the measured mid-upper-arm circumference and taken 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 used for the definition of hypertension (systolic blood pressure-SBP$\geq$140 mmHg and/or diastolic blood pressure-DBP$\geq$90 mmHg). In the current study, hypertension was considered as a continuous variable. Additionally, self-reported hypertension was defined as previously diagnosed hypertension by a physician based on a positive answer to the question "*have you been diagnosed with hypertension?*" A similar criterion was used to define a previous diagnosis of diabetes.

### 7.2.7 Physical activity

Objective measurement of PA was done using the ActiGraph GT3X (ActiGraph, Shlimar, FL, USA). The technical specifications and performance characteristics of the Actigraph accelerometer have been described elsewhere [25]. Actigraph data were considered complete if the participants had accelerometer counts for at least 10 hours per day for at least 4 days of the week. At least 30 minutes of continuous zero counts were regarded as accelerometer non-wear periods. The epoch length was set at 10 seconds and was later collapsed into 60-second epochs. We defined moderate physical activity (MPA) and vigorous physical activity (VPA) cut-points for adults using previously published recommendations [26]. PA is presented as moderate physical activity (MPA, min/week), vigorous physical activity (VPA, min/week) and the combined moderate-to-vigorous (MVPA, min/week). The total minutes spent in objective MVPA was calculated by summing minutes per week of moderate- and vigorous-intensity activity. The study used the following cut-off points: moderate PA (2691-6166 counts per minute), and vigorous PA (6167-9642 counts per minute). The data were scored and interpreted using the software program ActiLife version 6 (ActiLife software; Pensacola, FL; USA). Accelerometers have been recognized as a valid and objective tool to assess free-living physical activity [27].

### 7.2.8 Built environment attributes

Built environment attributes were assessed using Global Information System (GIS) -derived variables. The location of each participant's residence was geocoded using ArcGIS 9.3 (ESRI Inc). Three road distance buffers (500 m, 1000 m and 1600 m) were generated around each participant's household [28]. Neighbourhoods were defined by constructing a buffer zone around each participant's home, based on a street network [14]. Consequently, the study used road distance buffers that reflected walking times of approximately 5–7 min (500 m), 10–12 min (1000 m) and 15–18 min (1600 m) at a normal walking pace [29]. A radial distance of 500m was used to indicate the most accessible space to allow for an elderly population. The study measured destination proximity to services and facilities such as the community centre (police station, library, health clinic and open space), distance to transit stops (taxi rank) and retail shopping centre (shopping mall). We generated all GIS attributes through ArcGIS 9.3. GIS data were provided by the Faculty of Engineering and Built Environment from University of Cape Town.



### 7.2.9 Statistical analysis

The descriptive data are presented as means ± standard deviation or count and percentages. The Chi squared test and t-test were used to compare socio-demographic characteristics selected CVD risk factors and built environment attributes by gender. Linear regression analyses were executed to assess the association between built environment attributes, and selected CVD risk factors including WC, WHR, BP, BMI and physical activity. Statistical tests were considered significant at $p < 0.05$. All data were analysed using SPSS® version 22 for Windows (IBM Corp: Armonk New York).

## 7.3 Results

### 7.3.1 Descriptive characteristics of the participants

The socio-demographic characteristics of the participants are displayed in Table 7.1. Of the 341 participants, 77.4% were female and the mean age was 56.1±10.6 years. Furthermore, 41.9% of the participants were unmarried, 61.9% had completed secondary school, 61.9% were unemployed, 93.5% earned between ZAR2000-5000 per month and 92.7% did not own a car. These characteristics were similar between men and women. Additionally, 28.2% of the participants smoked while 35.2% were current drinkers, with significant gender differences in both smoking and drinking status (both $p \leq 0.005$), Table 7.1.

The prevalence of self-reported diagnosed diabetes was 23.2% overall, with no gender differences, whereas the prevalence of self-reported hypertension was 31.2% and 49.6% for men and women, respectively ($p = 0.004$) (Table 7.1). The mean blood pressure level was 142.7 ± 22.7 mmHg (systolic) and 84.6 ± 12.5 mmHg (diastolic). Differences in mean BP by gender were significant for diastolic blood pressure ($p = 0.047$). The mean WC ($p<0.001$) and BMI ($p<0.001$) were higher in women than in men, while WHR was similarly distributed across both genders (all $p \geq 0.234$), Table 7.1.

The mean time spent in objectively measured physical activity (minutes per week) was 311±117 (MPA), 3.5±3.4 (VPA) and 321±121 (MVPA). There were no gender differences across physical activity intensities ($p>0.509$), Table 7.1. The GIS buffers from participants' homes were predominantly 500 m (61.0% of participants) for the community centre, 500 m (42.8 %) for the shopping centre and 500 m (49.6%) for the taxi or transit station. Likewise, no gender differences were noted across BE attributes ($p > 0.05$), Table 7.1.

**Table 7.1 Descriptive characteristics of the participants by sex**

| Variables | Male | Female | P-value | All |
|---|---|---|---|---|
| **N (%)** | **77 (22.6)** | **264 (77.4)** | | |
| **Age** (M [d] ± SD) | 54.4±11.9 | 56.6±10.2 | 0.101 | 56.1 ± 10.6 |
| **Socio-demographic (N (%))** | | | | |
| **Marital status** | | | 0.093 | |
| Never | 29 (37.7) | 114 (45.2) | | 143 (41.9) |
| Current | 28 (36.4) | 56 (21.2) | | 84 (24.6) |
| Co-habiting | 5 (6.5) | 20 (7.6) | | 25 (7.3) |
| Single | 3 (3.9) | 11 (4.2) | | 14 (4.1) |
| Widowed/divorced/separated | 12 (15.6) | 63 (23.9) | | 75 (22.0) |
| **Education Level** | | | 0.581 | |
| Primary | 19 (24.7) | 67 (25.4) | | 86 (25.2) |
| Secondary | 46 (59.7) | 165 (62.5) | | 211 (61.9) |
| Vocation | 7 (9.1) | 24 (9.1) | | 31(9.1) |
| College/University | 5 (6.5) | 8 (3.0) | | 13 (3.8) |
| **Employment Status** | | | 0.332 | |
| Full time | 10 (13.0) | 21 (8.0) | | 31 (9.1) |
| Part time | 7 (9.1) | 14 (5.3) | | 21 (6.2) |
| Self employed | 3 (3.9) | 12 (4.5) | | 15 (4.4) |
| Unemployed | 41 (53.2) | 170 (64.4) | | 211 (61.9) |
| Retired | 16 (20.8) | 47 (17.8) | | 63 (18.5) |
| **Salary levels** | | | 0.704 | |
| ≤ZA R 2000 | 3 (3.9) | 17 (6.4) | | 20 (5.9) |
| ZAR 2000 – 5000 | 72 (93.5) | 240 (90.9) | | 312 (91.5) |
| ≥ZAR 5000 | 2 (2.6) | 7 (2.7) | | 9 (2.6) |
| **Smoking** | | | **0.005** | |
| Never | 29 (37.7) | 155 (58.7) | | 184 (54.0) |
| Current | 30 (39.0) | 66 (25.0) | | 96 (28.2) |
| Former | 18 (23.4) | 43 (16.3) | | 61 (17.9) |
| **Alcohol** | | | **0.004** | |
| Never | 22 (28.6) | 122 (46.2) | | 144 (42.2) |
| Current | 39 (50.6) | 81 (30.7) | | 120 (35.2) |
| Former | 16 (20.8) | 61 (23.1) | | 77 (22.6) |
| **Own a car** | | | 0.340 | |
| None | 74 (96.1) | 242 (91.7) | | 316 (92.7) |
| One | 1 (1.3) | 13 (4.9) | | 14 (4.1) |
| Two or more | 2 (2.6) | 9 (3.4) | | 11 (3.2) |

*M [d], mean; SD, standard deviation; bold is significant p value*

**Table 7.1 continues**

| CVD risks - self-reported | Male | Female | P-value | All |
|---|---|---|---|---|
| **Diabetes** | | | 0.384 | |
| No | 62 (80.2) | 200 (75.8) | | 262 (76.8) |
| Yes | 15 (19.5) | 64 (24.2) | | 79 (23.2) |
| **Hypertension** | | | **0.004** | |
| No | 53 (68.8) | 133 (50.4) | | 186 (54.5) |
| Yes | 24 (31.2) | 131 (49.6) | | 155 (45.5) |
| **CVD risks - screened (M [d] ± SD)** | | | | |
| WC cm | 88.2±18.8 | 100.5±23.4 | **<0.001** | 97.7±23.0 |
| WHR cm | 0.9±0.1 | 0.9±0.1 | 0.234 | 0. 9±0.1 |
| BMI (kg/m²) | 26.3±6.5 | 32.9±6.9 | **<0.001** | 31.4 ± 7.3 |
| SBP (mm Hg) | 139.3±23.0 | 143.7±22.6 | 0.126 | 142.7 ± 22.7 |
| DBP (mm Hg) | 82.1±12.5 | 85.3±12.5 | **0.047** | 84.6 ± 12.5 |
| **Accelerometer physical activity (M [d] ± SD)†** | | | | |
| Moderate (minutes per week) | 300.0±111.8 | 314±118.5 | 0.540 | 311.4± 116.9 |
| Vigorous (minutes per week) | 3.9±3.1 | 3.4±3.5 | 0.509 | 3.5 ± 3.4 |
| Total MVPA (minutes per week) | 309.3±115.8 | 324.1 | 0.543 | 321.0± 121.4 |
| **Objectively measured built environment (N (%))** m[e] | | | | |
| **Community centre** | | | 0.835 | |
| 500 | 49 (63.6) | 159 (60.2) | | 208 (61.0) |
| 1000 | 12 (15.6) | 48 (18.2) | | 60 (17.6) |
| 1600 | 16 (20.8) | 57 (21.6) | | 73 (21.4) |
| **Shopping mall** | | | 0.124 | |
| 500 | 28 (36.4) | 118 (44.7) | | 146 (42.8) |
| 1000 | 37 (48.1) | 93 (35.2) | | 130 (38.1) |
| 1600 | 12 (15.6) | 53 (20.1) | | 65 (19.1) |
| **Taxi Station** | | | 0.693 | |
| 500 | 39 (50.6) | 147 (55.7) | | 169 (49.6) |
| 1000 | 9 (11.7) | 31 (11.7) | | 105 (30.8) |
| 1600 | 29 (37.7) | 86 (32.6) | | 67(19.6) |

*M [d], mean; SD, standard deviation; CVD, cardiovascular disease; WC, waist circumference; WHR, waist hip ratio; †subsample of 155. m[e]; meter; bold is significant p value*

### 7.3.2 Associations of objectively assessed built environment attributes and selected CVD risk factors

In univariate linear regression models (Table 7.2), distance from a participant's home to the community centre was associated with higher diastolic blood pressures. Relative to 500 m, residing 1000 m away from the shopping centre was associated with 2.30 (0.53-4.09) km/$m^2$ higher BMI, while residing 1600 m away was associated with 0.02 (-0.00 to 0.060) higher WHR, 2.40 (0.14-4.57) kg/$m^2$ higher BMI, 43.30 min/week (-2.76 to 89.34) lower MPA and 46.24 min/week (-1.54 to 93.90) lower MVPA. Residing 1000 m away from the taxi rank was associated with 5.22 (1.52 to 8.88) mmHg lower DBP, while residing 1600 away was associated with 42.34 min/week (-3.74 to 88.30) lower MPA and 46.40 min/week (-1.35 to 94.06) lower MVPA, Table 7.2.

## Table 7.2 Univariable linear regression of objectively measured built environment attributes with selected CVD risk factors

| Variables | WC | WHR | BMI | SBP | DBP | MPA† | VPA† | MVPA† |
|---|---|---|---|---|---|---|---|---|
| | β (95% to CI) | β (95% to CI) | β (95% to CI) | β (95% to CI) | β (95% to CI) | β (95% to CI) | β (95% to CI) | β (95% to CI) |
| **Objectively measured Built environment (m)** | | | | | | | | |
| **Community centre** | | | | | | | | |
| 500 (ref) | | | | | | | | |
| 1000 | 0.90 (-17.69 to 19.54) | 0.00 (-0.02 to 0.03) | 0.70 (-1.81 to 3.21) | 3.91 (-2.67 to 10.48) | **4.02*** (0.38 to7.62) | -63.23 (-127.18 to 0.73) | 0.01 (-1.60 to 1.61) | 31.44 (-24.42 to 87.30) |
| 1600 | 6.91 (17.69 to 19.54) | 0.00(-0.02 to 0.05) | 1.84 (-0.28 to 3.95) | 5.90 (-2.12 to 13.51) | **5.43*** (1.13 to 9.73) | -26.07 (180.00 to 27.86) | -0.26 (-1.66 to 1.45) | -40.25 (-88.99 to 8.48) |
| **Shopping centre** | | | | | | | | |
| 500 (ref) | | | | | | | | |
| 1000 | 1.31 (-14.71 to 17.25) | 0.01 (-0.12 to 0.03) | **2.31*** (0.53 to 4.09) | 4.63 (-0.74 to 10.09) | -4.51 (-8.36 to 0.68) | 23.23 (-13.97 to 60.38) | -0.01 (-1.19 to 1.17) | -21.61 (-60.11 to 17.00) |
| 1600 | 7.52 (-5.46 to 20.53) | **0.0**2*(-0.00 to 0.06) | **2.40*** (0.14 to 4.57) | 2.82 (-4.01 to 9.62) | -0.32 (-3.24 to 2.67) | -43.30(-89.34 to 2.76) | 0.12 (-1.58 to 1.83) | -46.24 (-93.90 to 1.54) |
| **Taxi Rank** | | | | | | | | |
| 500 (ref) | | | | | | | | |
| 1000 | -6.33 (-19.08 to 6.47) | 0.02 (-0.01 to 0.06) | -1.71 (-4.32 to 0.98) | -2.21 (-10.28 to5.38) | **-5.22**** (-8.88 to -1.52) | -30.40 (-83.18 to 22.31) | 0.40 (-0.83 to 1.55) | -32.33 (-87.00 to 22.38) |
| 1600 | -3.92 (23.70 to 16.00) | 0.02 (-0.13 to 0.03) | -1.60 (-4.12 to 0.92) | 1.73 (-3.67 to 7.02) | 2.24 (-0.81 to 5.14) | -42.34 (-88.3 to 3.74) | -0.30 (-1.96 to 1.36) | -46.41 (-94.06 to 1.35) |

*WC, waist circumference; WHR, waist hip ratio; BMI, body mass index; SBP, systolic blood pressure; DBP, diastolic blood pressure; MPA, moderate physical activity; VPA, vigorous physical activity; MVPA, moderate vigorous physical activity; † , subsample of 155; β, beta coefficient; CI, confidence interval; m, meter;* ***p<0.05;* ****p<0.01*

In multivariate regression models, adjusted for sex and age, the distance to a community centre remained associated with BMI, DBP and MVPA; the distance to shopping centre was associated with BMI and SBP, while distance to taxi rank was borderline associated with SBP (Table 7.3). In an extended multivariable regression model even after adjusting for history of hypertension, distance to a community centre remained positively associated with DBP.

**Table 7.3 Multivariable linear regressions of objectively assessed built environment with CVD risk factors adjusted for age and sex [f]**

| Variables | WC | WHR | BMI | SBP | DBP | MPA† | VPA† | MVPA† |
|---|---|---|---|---|---|---|---|---|
| | **β (95% to CI)** | **β (95% to CI)** | **β (95% to CI)** | **β (95% to CI)** | **β (95% to CI)** | **β (95% to CI)** | **β (95% to CI)** | **β (95% to CI)** |
| **Objectively measured built environment (m)** | | | | | | | | |
| **Community centre** | | | | | | | | |
| 500 (ref) | | | | | | | | |
| 1000 | -5.28 (-14.76 to 3.20) | -0.00 (-0.04 to 0.04) | **4.70*****  (2.06 to 7.34) | 4.08 (-4.67 to 12.82) | **4.97*** (-0.00 to 9.95) | -29.10 (-82.60 to 24.43) | 0.0 (-1.60 to 1.64) | -34.56 (-90.00 to 20.90) |
| 1600 | -4.66 (-11.03 to 1.72) | -0.01 (-0.04 to 0.02) | 2.37 (-0.30 to 5.02) | 6.21 (-2.59 to15.01) | **6.58**** (1.57 to 11.58) | -60.90 (-124.25 to 2.44) | -0.22(-2.13 to 1.70) | **-69.30 ***(-134.92 to -3.70) |
| **Shopping centre** | | | | | | | | |
| 500 (ref) | | | | | | | | |
| 1000 | 5.34 (-1.82 to 12.49) | 0.01 (-0.03 to 0.04) | 1.79 (-0.32 to 3.89) | **7.99*** (0.03 to 13.95) | -1.82 (-5.79 to 2.14) | -61.50 (-208.99 to 86.00) | -1.72 (-10.19 to .75) | -60.79 (-212.73 to 91.16) |
| 1600 | 9.14 (-3.33 to 21.61) | 0.0 (3-0.03 to 0.09) | **4.78**** (1.11 to 8.45) | -0.63 (-9.51 to 8.26) | -0.68 (-7.59 to 6.22) | -127.22 (-358.73 to 104.29) | 1.50 (-6.44 to 9.44) | -124.81 (-363.00 to 113.68) |
| **Taxi Rank** | | | | | | | | |
| 500 (ref) | | | | | | | | |
| 1000 | -1.12 (-10.29 to 8.05) | 0.01 (-0.03 to 0.05) | -0.11 (-2.81 to 2.59) | 0.67 (-8.26 to 9.61) | 1.50 (-3.59 to 6.58) | 22.13 (-147.83 to 192.09) | -2.78 (-11.78 to 6.22) | 21.17 (-153.92 to 196.26) |
| 1600 | -5.99 (-14.10 to 2.12) | -0.01 (-0.05 to 0.03) | -1.68 (-4.07 to 1.70) | 7.71 (-0.19 to 15.60) | 3.35 (-1.14 to 7.84) | 102.31(-57.00 to 261.61) | 3.56 (-2.23 to 9.35) | 104.62 (-59.49 to 268.73) |

[f] *adjusted for age and sex; WC, waist circumference; WHR, waist hip ratio; BMI, body mass index; SBP, systolic blood pressure; DBP, diastolic blood pressure; BP, blood pressure; MPA, moderate physical activity; VPA, vigorous physical activity; MVPA, moderate vigorous physical activity; †,sample of 155; β, beta coefficient;* ***p<0.05;* ****p<0.01;* *****p<0.001*

## 7.4 Discussion

In the current study, participants, in general, met the WHO recommendations of 150 minutes/week for MVPA, but with very low levels of VPA. In univariate regression analysis, we observed statistically significant positive relationships between objectively measured distances to the shopping centre and body mass index. While, distance to a community centre was positively associated with diastolic blood pressure, proximity to a shopping centre and taxi rank were was inversely associated with diastolic blood pressure. Built environment attributes tended to be inversely associated with physical activity. After adjusting for age and gender, distance to a community centre (1600 m) and taxi rank (1000 m) lost their significance with high body mass index and diastolic blood pressure; while after further adjustment for history of hypertension, proximity to a shopping centre was no longer associated with systolic blood pressure.



This study supports the growing evidence that a walkable neighbourhood environment is associated with fewer CVD risk factors [20, 30, 31]. A number of potential advantages have been suggested that explain the beneficial effects of living near community services, including increased physical activity, and lowering obesity and hypertension. However, the mechanism by which the interaction between built environment attributes and CVD risk factors occurs has yet to be fully elucidated. Nevertheless, one possible interpretation could be that the short distance from the respondents' home to the community centre, for example, increases physical activity through walking, thereby lowering the risk of developing obesity and hypertension. Considering the low wages of our participants and the low prevalence of car ownership, it is likely that most participants were relying on walking and public transport essentially.

Another potential mechanism for the relationship between proximity to a community centre, and health outcomes may be found in a study from the Netherlands, where high quality, open public space was associated with a lower systolic blood pressure [32]. This implies public open space may affect health, not only through providing physical activity space, but also through its contribution to environmental improvement, such as air quality, social cohesion and disorder. In addition, it is possible that individuals living close to the health center are more likely to access the facility and adhere to anti-hypertensive drugs. For example, in Ethiopia individuals from long distant areas were less likely to be adherent to hypertension treatment as compared to those who resided closer to health centres [33].

In this study setting, the shopping centre was located near to the rail station, meaning that poor residents staying far away will usually need to take public transport to access the shopping centre, thus resulting in less frequent walking trips. In addition, a proportion of our participants, who were employed, had to cover long distance to and from jobs. As a consequence, they may have had less time to shop and prepare healthy food for their households or may have had to depend on street food and 'spaza' shops for meals clustered near rail or bus stations, which were less unhealthy [34]. All these factors aggravate participants' risk for health inequalities through unhealthy food choices and decreased physical activity, and subsequently favouring the development of cardio-metabolic risk factors such as obesity and hypertension.



## 7.5 Limitation and strengths

The present study has some limitations. Its cross-sectional design did not allow defining causality association among characteristics. The study area, the Langa Township, has limited variability in land use, and consequently only variables available in the GIS database could be examined. For example, there was no GIS data available on local corner shops (spaza) considered to be selling unhealthy food. Therefore, more GIS data are required to understand the associations between neighbourhood environment and CVD risk factors in South Africa. In addition, available variables were not categorized into contrasting socioeconomic levels (low/high) and built environments (low/high). Hence, these results are not applicable to other neighbourhoods in Cape Town. The study's sample size may have been too small especially for accelerometer to observe clear differences and trends. Another concern is that although the accelerometers provide objective measures that remove self-report biases, they do not capture all forms of PA accurately. For example, participants were asked to remove the monitors during activities involving water, thus, excluding swimming. The study also had strengths. This is the first study to provide evidence on the direct association between objectively measured built environment attributes with, BMI, SBP, DBP and physical activity in an Africa context.



## 7.6 Conclusion

The current study has provided for the first time, evidence to support an association between access to community resources and amenities, as well as distance or proximity to community and shopping centres, as well as transit stops, along with selected CVD risk factors (BMI, SBP, DBP and PA). The current study indicates that public health approach such as increasing proximity and access of community services in neighbourhoods would potentially assist in reducing population's cardio-metabolic disease risk, by creating opportunities for physical activity and healthy food choices. However, similar studies should be replicated in other African countries before any firm conclusions can be ascertained.

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# Chapter 8

## Study summary, Discussion, Public Health Implications and Recommendations

## 8.1 Summary of the findings

***Background***

Currently, South Africa is undergoing a rapid epidemiological transition, and increased urbanisation is associated with an increase in CVD risk factors. Studies have revealed that BE attributes described as physical or man-made features, such as sidewalks, streetlights, traffic and parks, which may promote or discourage different domains of PA [1]. Therefore, the results of this thesis have implications for future research and highlight current issues that will help improve population health and reduce CVD risk factors. Furthermore, there is a scarcity of research data, especially in an African context, which has subjectively and objectively measured BE attributes and CVD risk factors such as PA, obesity and BP.

***Aim***

The aim of this thesis was to assess the relationship between BE attributes and PA among urban and rural adult South Africans and to examine the effect of this association, if any, on cardiovascular risk factors. In this study, further attempts were made to investigate the associations of objectively measured BE attributes and PA and CVD risk factors.

***Summary of the methodology***

This study was embedded in the global, longitudinal PURE study, undertaken in 23 countries of which South Africa is a partner. In the PURE study, the environmental changes, the societal influences on lifestyle, the risk factors and cardiovascular disease are tracked. In South Africa, the urban arm of this study was undertaken at the Cape Town site in Langa Township, while Mount Frere in the Eastern Cape formed the rural arm.

For this thesis a cross-sectional, analytical study was used which was conducted in three phases. **Phase I**, was a systematic review of literature to examine the influence of built environmental attributes on CVD risks and major CVD outcomes. **Phase II** involved secondary data analysis from the Cape Town (urban) and Mount-Frere (rural) sites of PURE study conducted in 2009. In this phase of the study the prevalence and socio-demographic factors associated with PA were determined; the association between perceived environmental attributes and leisure-time and transport-related PA investigated. The association between the perceived BE and prevalence of hypertension and the extent to which PA mediates the association between perceived neighbourhood aesthetics and overweight/obesity was also explored. In **Phase III**, the relationship between objectively-measured attributes of BE with BMI, SBP, DBP and PA was investigated. The IPAQ, NEWS, GIS and accelerometers were used to collect data. Descriptive data and logistic and linear regressions were applied for the statistical analyses.

***Summary of the results***

In summary, some of the subjectively and objectively measured BE attributes were associated with cardiovascular risk. Females in urban areas, as compared to their male counterparts, were less likely to participate in moderate to vigorous PA, and were more likely to be overweight/obese, with a high self-reported hypertension. The findings from this study have been presented in seven Chapters. For each study a summary of these findings is shown in Table 8.1 below:

**Table 8.1 Summary of the findings**

| No. | Chapter | Title | Results |
|---|---|---|---|
| 01 | 2 | Built environment, selected risk factors and major cardiovascular disease outcomes: A systematic review | Neighbourhood environmental attributes were found to be significantly associated with cardiovascular disease risk and outcomes in the expected direction in this study. For example, residential density, safety from traffic, recreation facilities, street connectivity and high walkable environment were associated with PA. Furthermore, high walkable environment, fast-food restaurants, and supermarket/grocery stores were associated with BP, BMI, diabetes mellitus and the metabolic syndrome. Additionally, high-density traffic, road proximity and fast-food restaurants were associated with CVD outcomes. |
| 02 | 3 | Prevalence and socio-demographic correlates of physical activity levels among South African adults in urban and rural communities | In this study, most of participants engaged in moderate-to-high PA. After adjusting for all variables the regression models showed that women were less likely to engage in high PA than men. In all interactions, PA varied with age, marital status, education and occupation, even across urban and rural participants. For instance, in urban settings, those with secondary education were more likely to engage in moderate PA, and single people were more likely to engage in both moderate and high PA. |
| 03 | 4 | Association between perceived built environmental attributes and physical activity among adults in South Africa | After adjusting for gender and age, proximity to transit stops was significantly associated with leisure-time PA and walking for leisure, while the presence of sidewalks predicted the likelihood of walking for leisure. Conversely, traffic along streets was associated with lower leisure-time PA and walking for leisure. Likewise, street lights at night increased the likelihood of walking for leisure, but the high crime rate during the day lowered leisure-time PA. Further observations made were that transport-related PA was independently related with distance between intersections and the presence of four-way intersections. Finally, in this study, pleasant scenery (interesting things to look at) was found to be associated with performing 150 minutes per week or more transport-related PA, while crosswalks were also found to encourage transport-related PA. |

BMI: body mass index; BP: blood pressure; CVD: cardiovascular disease; PA: physical activity

**Table 8.1 continues**

| | | | |
|---|---|---|---|
| 04 | 5 | Association between perceived BE and prevalent hypertension among South African adults | In an adjusted model, land-use mix-diversity was significantly associated with self-reported hypertension. In similar multivariable models, the direction and magnitude of the effects was mostly similar for the outcomes of 'screen-detected hypertension', which was further predicted by perceived lack of safety from traffic. |
| 05 | 6 | Does physical activity mediate the association between perceived neighbourhood aesthetics and overweight/obesity among South African adults living in selected urban and rural communities? | In this study, after adjusting for PA in model 2, overweight/obesity was found to be significantly associated with neighbourhood aesthetics and PA. In expanded multivariable models, after adjusting for aesthetics, PA, gender, age, education and location, were associated with overweight/obesity. In model 1 of the mediation analysis both aesthetics and PA were negatively associated with overweight and obesity. However, after adjusting for age, gender, education and location, there was no evidence to support a significant mediating effect of PA in the relationship between aesthetics and overweight/obesity. |
| 06 | 7 | The relationship of objectively measured built environment walkability with selected cardiovascular risk factors in a South African urban setting | In the adjusted model, distance to a community centre (1000 m) was positively related to BMI and DBP. In addition, distance to a community centre (1600 m) was positively related to DBP and negatively associated with moderate to vigorous PA. Proximity to a shopping centre (1000 m and 1600 m) was positively related to SBP and BMI respectively. |



BE: built environment; PA: physical activity; BMI: body mass index; DBP: diastolic blood pressure; SBP: systolic blood pressure

## 8.2 Discussion

For this thesis subjective and objective methods were used to assess the BE attributes. In this study, various BE attributes were found to be associated with CVD risk factors as well as CVD outcomes. In both subjective and objective measures, most of the participants engaged in moderate PA, which varied across socio-demographic factors. Likewise, proximity to community facilities was associated with PA, obesity and hypertension, but PA was not a mediating factor between aesthetic environment and obesity.

These findings broadly concur with a substantial body of research showing that BE attributes, either subjectively or objectively measured, are associated with cardiovascular risk factors [1,2]. For instance, attributes of BE have been reported to be significantly correlated with obesity [3], PA [4], hypertension [5] and CHD [6]. Researchers, in other studies, have observed that access to shopping malls or supermarkets were directly related to transport-related walking [7], obesity [8] and BP [9]. This seems to suggest that there may be a threshold by which environmental changes are associated with PA and that low levels of exposure to certain environmental features may not be effective in increasing PA levels [10]. These results contribute to the scarce data on the benefits of walkable environment on health. For example, the health benefits of PA on CVD risk factors and CVD outcomes are well reported [11]. For instance, low street connectivity has been linked to hypertension [12].



There are various possible explanations for this mechanism, for example, these features may reflect the availability of utilitarian destinations, which encourage walking or better choices on healthy food. People living in neighbourhoods with better PA and healthy food environments have shown to be more physically active, walk more and have a lower risk of obesity than communities with poor walkability [13].

Furthermore, sidewalks alongside streets, which represent an aesthetic neighbourhood environment and neighbourhood attractiveness, are consistently associated with increased recreational walking, because they attract people and motivate them to walk. In addition, street lighting may support walking by increasing the sense of security at night or early in the morning. Likewise, good street connectivity provides more walking-route choices and more often a direct route between place of origin and destination.

On the contrary, with increased pedestrian crime, there is likely to be a lower sense of safety and social norms for any kind of PA. Absence of traffic-control devices and regulation of vehicular traffic increases the uncertainty for regular use of roads or streets. This factor makes it unfavourable or difficult for community members to cross streets and thus, may reduce the amount of outdoor physical activity or walking. These mechanisms may adversely impact on PA, which, in turn, increases the risk of obesity and the development of hypertension.

In this study, PA was also found to vary across socio-demographic characteristics. In other studies, age, education and occupation were shown to be related to PA [14,15]. The positive effect of education on health arises from the fact that higher educated people usually have better job opportunities, higher annual income, improved housing, better access to nutritious foods and access to health insurance [16]. According to Shaw [17], highly educated individuals may also be better equipped to maintain regular physical activity after the onset of morbidity and disability. The author further documents that higher levels of education provide individuals with some advantages that are likely to promote physical activity during age-related changes in abilities, including increased knowledge about its benefits, some sense of personal control and self-efficacy for physical activity, healthier influences from social network members, and access to resources that facilitate physical activity [17].

In addition, the observed association between urban dwelling and PA could be due to people tending to walk, as distances to destinations are small and easily reached by walking. For example, walkable neighbourhoods with a wide range of local destinations to go to, as well as a diverse use of land, encourage physical activity among individuals [18]. Those who were single were more likely to engage in moderate PA. In this case, interpersonal relationships may influence PA and establish new social networks and help individuals to learn about PA and its benefits. Single and educated participants may use the social network to meet and make new friends [19].



Furthermore, the amount of PA decreased by age, as demonstrated in this study. Though the mechanism by which age may affect daily PA is not fully understood. One possible reason for a reduction in PA with age is a decrease in gait speed to minimize total energy expenditure and to offset the decline in walking efficiency [20,21].

## 8.3 Limitations and Strengths

The results in this thesis are not without limitations. First, the study was based on a cross-sectional design, which did not allow for the investigation of causal relationships among characteristics. Second, the results were restricted to adults, and further only included two provinces of South Africa. Therefore, these findings may not be applicable countrywide.

There were other study-specific limitations as mentioned in the applicable chapters of the thesis. For instance, there were no systematic review studies that identified the association between neighbourhood environmental attributes and CVD risk and major CVD in an African context. This made comparing this study with those in developing countries very challenging.

Another limiting factor of this study was that the core of the data analysed, PA and BE, were assessed subjectively with IPAQ and NEWS. Therefore, these self-reporting measures may have introduced reporting or recall bias into the study. In addition, data were lacking on socio-economic status, such as income, which may confound the associations between environmental attributes and related CVD risk factors in this study.

Worth noting is that despite availability of secondary data sets to the researcher, there are some limitations that need mentioning. For example, it was time consuming to familiarise with data sets and selecting variables, including documenting the sampling design and procedures. It was also time consuming getting permission to access such data sets for this study. Also, as the number of measures and assessments of interest increased in the data sets, so did the increase in missing data. Therefore, this thesis involved a sub-analysis with a reduced sample size because of missing data. Thus, the study lacked sufficient statistical power to detect all the significant associations. In addition, individual bias may have occurred, i.e. differences between those who did and did not complete the questionnaires in a community.

Important to mention, is that the use of the GIS and accelerometers in this study had some limitations. For example, participants were not asked to define what they considered to be their neighbourhood, and the GIS boundaries of their neighbourhood might not have matched that of a person's perceived neighbourhood area. Additionally, the GIS database available for the Langa Township neighbourhoods did not include information on the presence of graffiti and vandalism, sidewalk presence, and sidewalk obstructions. Similarly, there was no consensus regarding the distance to use between household and proximity to the services in the neighbourhood. For this reason, comparing results of the current study with other global studies makes it difficult. Consequently, before generalising the results of the current study, there is need to conduct an observational audit evaluation of the neighbourhoods.

A final weakness of the current study is that accelerometer cannot capture upper extremity movement, which may lead to underestimating certain household activities, such as housework. This study found that the majority of the participants were less skilled (homemakers) and thus it is possible that their daily household chores could have been under reported.

This study has some significant strength worth mentioning. This is the first study to assess a relationship between BE attributes and selected CVD risk and major CVD in an African context. This study was based on a representative sample of the urban and rural South African population which was assessed using both subjective and objective standardized methods for surveying BE attributes and risk factors for CVD.



## 8.4 Public health implication

Results from this study are of public health significance, as these will provide research-based information for future research studies and public health programmes aimed at health promotion and prevention of CVD in urban and rural communities. In the current study, existing relationships were examined between BE and selected CVD risk factors, and thereby creating a foundation for our understanding on the role of BE in public health research. This is of great importance, as indicated by the results of the current study in which some associations were observed between CVD risk factors and the BE attributes. This implies that other, seemingly cofounders and neighbourhood attributes may reduce any appreciable impact that the BE may have on CVD risks. Therefore, it is imperative that these factors be systematically identified and targeted in future studies before any intervention is implemented.

Currently, there is scarcity of research data, especially in African context, which has both subjectively and objectively measured BE attributes and CVD risk factors, such as PA, obesity and BP. For this reason, the results instigated by this study provide more information on methods underlying the assessment of the BE and selected CVD risks and outcome in an African environment. It is my opinion that embodying this approach of assessing the BE and CVD risk factors will promote further understanding on the suitable and precise CVD interventions for urban and rural adult South African populations.



## 8.5 Recommendation

This thesis will contribute to the large body of evidence that BE has the potential to change health risk factors in communities. However, further work is needed to understand the broad context of BE in various communities which can eventually be translated into population knowledge and provide meaningful interventions for improving population health and reducing CVD.

Despite participants being moderately active, various determinants were identified that affect level of PA. In addition, various BE attributes that are associated with CVD risk factors were also identified for urban and rural communities. In this thesis, the findings present a number of implications for future studies, policy and interventions:

- A number of strategic actions are needed to explore any association between CVD and other environmental attributes, such as proximity to stores selling tobacco, alcohol, air-polluted areas and density of food environment in order to have a broader understanding of other moderating effects.
- There is need to conduct objective assessment of PA and BE in urban and rural communities to have a variation before implementing broad intervention policies in communities.
- In this study tools that have been developed and tested in developed countries were employed, thus, there is a need to replicate similar studies using a locally-developed tool for the African context in future.
- In addition, using a longitudinal design for example to evaluate food-related environments that are related to overweight/obesity and hypertension should be considered in future studies.
- A further recommendation is that a comprehensive assessment of multiple attributes of the BE including mixed-land use, population density, retail ratio area, street connectivity and crime density is urgently needed to understand the implication on CVD.
- There is need to geocode neighbourhoods, be it rural or urban, to conduct more research on BE and its implication on health disparities.
- To accelerate the research on BE, there must be a deliberate policy on the accessibility of parcel data in all local governments. This will ensure health professionals develop community-based interventions based on research-based context of the neighbourhood.

- In this study, subjectively/objectively measured BE attributes have further been demonstrated to have been associated with CVD. As a result, improving neighbourhood environments may be an important avenue for public health interventions.
- There is need to expand research on the use of GIS and accelerometers in South Africa so that health implications of a variety of policies are objectively determined before any intervention is implemented in the neighbourhoods.
- To strengthen GIS-based measures, as used in this study, it is recommended that in future studies, evaluating BE along with environmental audit tools should be considered.

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**Appendices:**

*Appendix I:*

***Research Ethics Committee Letter of Approval***

OFFICE OF THE DEAN
DEPARTMENT OF RESEARCH DEVELOPMENT

UNIVERSITY of the
WESTERN CAPE

02 August 2013

**To Whom It May Concern**

I hereby certify that the Senate Research Committee of the University of the Western Cape approved the methodology and ethics of the following research project by Mr P Malambo (School of Public Health)

| | |
|---|---|
| Research Project: | Perceived built environment and physical activity: relationships and consequences on prevalent CVD and risk factors in urban and rural South Africa |
| Registration no: | 13/6/18 |

Any amendments, extension or other modifications to the protocol must be submitted to the Ethics Committee for approval.

The Committee must be informed of any serious adverse event and/or termination of the study.

*Ms Patricia Josias*
*Research Ethics Committee Officer*
*University of the Western Cape*

Private Bag X17, Bellville 7535, South Africa
T: +27 21 959 2988/2948 . F: +27 21 959 3170
E: pjosias@uwc.ac.za
www.uwc.ac.za

***Appendix II***

***Information sheet for individuals at baseline (PURE Study): Phase II of the study***

# UNIVERSITY OF THE WESTERN CAPE

Private Bag X 17, Bellville 7535, South Africa

***Tel: +27 21-959, Fax: 27 21-959***

**E-mail:**


**Prospective Urban and Rural study**

**Participant Information sheet**

Dear Participant

We are from the University of the Western Cape (UWC), and would like you to invite you to participate in this study.   This study will help researchers understand the way in which environmental/ societal factors influence the development of cardiovascular disease.

**What is this study about?**

This is a 15 year research study to understand the way in which environmental/ societal factors influence the development of cardiovascular disease. The South African study is part on an international project being carried out in 15 countries. The research will be carried out in 2 urban sites, and 2 rural sites in South Africa, involving 2,000 participants.  The research will look at a number of factors to understand whether, and how, they influence the development of cardiovascular disease.



**Who can participate in this research?**

Man and women between 35-60 years, who are not planning to move in the next 4 years

**What will be expected from the participants?**

All participants will be expected to answer a number of questionnaires (food intake, physical activity, socio-economics etc).  Blood (lipid test and glucose) will be draw and urine will be collected, no HIV tests will be done.  Heart function and lung function tests will be done as well as weight, height, waist, hip and other body measurements (grip test, and lung function test). All participants in the study will remain anonymous and all information will remain strictly confidential.  This means that your names will not be written on the questionnaire, only numbers will be used.

**What are the risks of this research?**

There are no known risks associated with participating in this research project.  Except for a slight discomfort when drawing bloods

**What are the benefits of this research?**

This research is not designed to help you personally, however you will receive a free medical examination and receive your own results informing you whether you have diabetes, high blood pressure, high cholesterol or high blood fats as well as your body size measurements every three years for the next 15 years.

The findings of this research can be used to help prevent, treat and manage diseases associated with heart disease and stroke in South African people.

**Can I withdraw from the study?**

Your participation in this research is completely voluntary. You may choose not to take part at all. If you decide to participate in this research, you may stop participating at any time. If you decide not to participate in this study or if you stop participating at any time, you will not be penalized or lose any benefits to which you otherwise qualify.

**Any further questions?**

More information may be obtained from Prof Thandi Puoane or Lungiswa Tsolekile at (021) 959 2809 or Ntsuki Xapa. If you would like to take part in the study, please read and sign the consent form.

Should you have any questions regarding this study and your rights as a research participant or if you wish to report any problems you have experienced related to the study, please contact:

Head of Department:

Dean of the Faculty of Community and Health Sciences:

University of the Western Cape

Private Bag X17

Bellville 7535



This research has been approved by the University of the Western Cape's Senate Research Committee and Ethics Committee.

Thank you very much

*Appendix III*

***Information sheet for individuals during phase III of the study***

UNIVERSITY OF THE WESTERN CAPE

Private Bag X 17, Bellville 7535, South Africa
*Tel: +27 21-959, Fax: 27 21-959*
E-mail:

## INFORMATION SHEET FOR INDIVIDUALS

**Project Title:** Perceived built environment and physical activity: relationships and consequences on prevalent CVD and risk factors in urban and rural South Africa.

**Dear Participant**

**What is this study about?**
This is part of PURE research project being conducted by the School of Public Health at the University of the Western Cape in collaboration with the Medical Research Council and University of Cape Town. We are inviting you to take part in this research project because you are a subject from the selected communities for this project.

**What will I be asked to do if I agree to participate?**
If you agree to take part in this study you will be asked to answer questions about the following areas of your life:

(a) Your education, occupation, and income;
(b) Your Social Support including group membership, and your network of friends;
(c) Tobacco and alcohol consumption;
(d) Medical history and the medication you are on;
(e) Your Family medical history;
(f) Questions about your sex life;
(g) Your feelings stress levels and whether you are self-driven ; and
(h) Your food intake and physical activity.

**What Measurements will be taken?**
You will be required to wear a meter (accelerometer) for <u>seven</u> complete days on your waist beginning when you wake up tomorrow morning. This meter records general movement and allows us to get a better idea of your overall activity level. We will NOT be able to tell what kind of specific activity is happening. At first, the belt may feel slightly awkward, but after a few hours, you will probably get to it and not notice it as much. It is <u>extremely</u> important for our study that you wear the meter properly. If it is not worn properly, we may have to send it back for to wear again. Please follow these instructions carefully;

- Wear the meter attached to the difficulty around your waist, just above your <u>right</u> hipbone. You can wear it either underneath or on top of your clothing
- Wear the meter so that the star sticker is facing up.
- Wear the meter <u>snug</u> against your body your body. If you have to, you can adjust the belt by pulling the end of the strap to make it tighter. Or, to loosen the belt, push more of the strap through the loop. <u>Wear the belt tight enough so that the meter does not move when you are being active.</u>
- Please put it on first thing in the morning- either just after you get out of bed or just after you shower/bath in the morning.
- Do not submerge the meter in water.
- Keep the activity meter on all day (bathing).

- At night, take it off right before you go to bed. You should be wearing the meter the meter for at least 12 hours each day.
- Do not let anyone else wear it.
- The meter has a very short battery life (10 days).
- Use a meter log book to record the dates and times that you put on and take off (please keep the log in a place where you will see it every day)
- If you cannot wear it by second day please contact Prof Thandi Puoane on the telephone below.

We will keep your personal information confidential. To help protect your confidentiality, your name will not be recorded. If we write a report or article about this research project, your identity will be protected to the maximum extent possible.

**What are the risks of this research?**
There are no risks involved in this study except feeling discomfort in the first few days of wearing the meter belt.

**What are the benefits of this research?**
This research may not help you personally but it will contribute to a better understanding of risk factors for CVD in the community. By knowing the risk factors, researchers will be able to develop physical activity interventions that will assist communities in preventing CVD.

**Do I have to be in this research and may I stop participating at any time?**
Your participation in this research is completely voluntary. You may choose not to take part at all. If you decide to participate in this research, you may stop participating at any time. If you decide not to participate in this study or if you stop participating at any time, you will not be penalized or lose any benefits to which you otherwise qualify. Your decision to participate or not in this research project or deciding to leave the study before it is over, will not affect or influence the benefits you get in this facility.

**What if I have questions?**
The head researcher and co-ordinator of this study is Prof. **Thandi Puoane**, at the School of Public Health at the University of the Western Cape. If you have any questions about the research study itself, please contact **Prof. Thandi Puoane. Her contact details are**:

**Tel: +27 21 959 3084**
**Cell: +27 21 82 707 5881**
**Fax: +27 21 959 2872**
**Email: tpuoane@uwc.ac.za**

Should you have any questions regarding this study and your rights as a research participant or if you wish to report any problems you have experienced related to the study, please contact:

**Dean of the Faculty of Community and Health Sciences :**
**Prof. J. Frantz (Acting)**
**University of the Western Cape**
**Private Bag X17**
**Bellville 7535**
**021-959 2631**
**jfrantz@uwc.ac.za**

***Appendix IV:***

***Socio-demographic Information of the study***

## NEWS-AFRICA SURVEY

This questionnaire has been used all over the world to understand more about where people live and how this may impact their ability and willingness to walk, move about, and play. This version has been adapted for use in sub-Saharan Africa countries for people aged 12-100 years. *Not all questions may apply to you*, but please try to answer all questions to the best of your ability.

**Subject ID**

☐☐ ☐☐☐ ☐☐☐ ☐☐ ☐☐☐☐ ☐☐☐

*Center #* *Community #* *Household #* *Subject #* *code #* *subject Initials*

**SECTION A: DEMOGRAPHIC INFORMATION**

Please respond to these questions about yourself.

1. What is your age ___________________(years old) or DOB_____________________?

2. What is your sex?

a) ☐ Male

b) ☐ Female

3. What is your marital status?

a) ☐ Never married b) ☐ Married c) ☐ Co-habiting d) ☐ Single

e) ☐ Widowed/separate/divorced.

4. What is your highest level of education?

a) ☐ None b) ☐ Primary school c) ☐ Secondary school d) ☐ Vocation school

e) ☐ College/university

5. What is your employment status?

a) ☐ Full-time employed b) ☐ Part-time employed c) ☐ Self-employed

d) ☐ Unemployed e) ☐ Retired

6. What is the **COMBINED** monthly income for your household?

a) ☐ < R 2000 b) ☐ R2000-R5000 c) ☐ R5000-R10000 d) ☐ R10 000-R15 000

e) ☐ >R 15 000

7. How many adults (aged 18 18 and above) live in your household most of the time?_______adults.

8. How long have you lived in your present address (house)?_____years and ______months

9. To which ethnic group do you belong?

a) ☐ Black b) ☐ Coloured c) ☐ Indian d) ☐ Other_______________

10. How many functioning vehicles/motorized transport (cars, trucks, motorcycles/bikes, tricycles) are available for use at your house?

a) ☐ None b) ☐ One c) ☐ Two d) ☐ Three or more

11. How often do you drive a vehicle?

a) ☐ less than once a week b) ☐ a few times a week

c) ☐ most days of the week d) ☐ everyday

## SECTION B: ANTHROPOMETRIC MEASUREMENT AND RISK FACTORS

**Physical measurements**

1. Weight ☐☐☐ . ☐ kg
2. Height ☐☐☐ . ☐ cm
3. waist circumference ☐☐☐ . ☐ cm
4. hip ☐☐☐ . ☐ cm

5. Blood Pressure *#1 Systolic* ☐☐☐ *# 1 Diastolic* ☐☐☐ *mmHg*

*# 2 Systolic* ☐☐☐ *# 1 Diastolic* ☐☐☐ *mmHg*

**Risk factor profile**

1. Which best describes your history of smoking?
   a) ☐ Former smoker b) ☐ Current smoker c) ☐ Never smoked
2. Which best describes your history of alcohol use?
   a) ☐ Former drinker b) ☐ Current drinker c) ☐ Never drank
3. Have you ever been diagnosed with any of the following? (***check all that apply***).
   a) Diabetes ☐ No ☐ Yes
   b) Hypertension/ high blood pressure ☐ No ☐ Yes
   c) Stroke ☐ No ☐ Yes
   c) Angina/heart attack/ coronary artery disease ☐ No ☐ Yes
   d) Heart Failure ☐ No ☐ Yes
   e) Other heart disease
4. Are you currently taking medication for diabetes? ☐ No ☐ Yes
5. Are you currently on treatment/medication for hypertension? ☐ No ☐ Yes
6 Are you currently on treatment/medication for stroke? ☐ No ☐ Yes
7. Are you currently on cholesterol lowering drugs? ☐ No ☐ Yes



**Biochemistry**

1. Where blood sample obtained?
   a) ☐ No b) ☐ Yes (***if yes, please provide the required information below***)
   a) ☐ Fasting Sample b) ☐ Non-Fasting Sample
   c) **Please print Blood label #** ☐☐☐☐☐☐

**2. Laboratory blood results (*please leave this section blank*)**

a. Plasma Glucose (*fasting*) ☐☐☐ . ☐ mg/dl

b. Cholesterol (*fasting*) ☐☐☐ . ☐ mg/dl

c. Triglycerides (*fasting*) ☐☐☐ . ☐ mg/dl

d. HDL (*fasting*) ☐☐☐ . ☐ mg/dl

e. LDL (*fasting*) ☐☐☐ . ☐ mg/dl

***Appendix V***

***Neigborhood Environment Walkability Scale***

## PURE/South Africa

**To be completed by a knowledgable household member**

**We are very grateful to you for your participation in this study. All information given by you will be held in strict confidence, and will be used for the purpose of this study only after removing any personal identifying information.**

# Assessing Neighbourhood Walkability

## INSTRUCTIONS

**Please answer EACH question by marking an X in ONE BOX on each line: (unless otherwise instructed)**

**[X]**

**OR**

**By writing number(s) in the spaces provided:**

**[1] [8]**

**OR**

**By specifying the answer on the line(s) provided**

July, 2007

**Household ID**

Centre # Community # Household #

**Subject Initials** F M L

**Today's date:** year month day

**We would like to find out more information about the way that you perceive or think about your neighbourhood. Please answer the following questions about your neighbourhood and yourself. Please answer as honestly and completely as possible and provide only one answer for each item. There are no right or wrong answers and your information is kept confidential.**

## A. Stores, facilities, and other things in your neighbourhood

**About how long would it take to get from your home to do the tasks listed below if you walked? Please put only one check mark for each task.**

| | 1-5 min | 6-10 min | 11-20 min | 21-30 min | 31+ min | Don't know |
|---|---|---|---|---|---|---|
| **1.** buy groceries | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| **2.** buy clothes | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| **3.** buy fruits and vegetables | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| **4.** eat at a restaurant | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| **5.** go to the bank | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| **6.** rent a video | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| **7.** buy medicines | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| **8.** go to work or school | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| ☐ check here if you do not have work away from home or do not attend school | | | | | | |
| **9.** go to the bus or trolley stop | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| **10.** go to the park | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |

**Household ID**

| | | |
|---|---|---|
| Centre # | Community # | Household # |

Subject Initials F M L

## B. Access to services

**Please check the answer that best applies to you and your neighbourhood. Both local and within walking distance mean within a 10-15 minute walk from your home.**

| | Strongly disagree | Somewhat disagree | Somewhat Agree | Strongly Agree |
|---|---|---|---|---|
| 1. I can do most of my shopping at local stores. | ☐ | ☐ | ☐ | ☐ |
| 2. Stores are within easy walking distance of my home. | ☐ | ☐ | ☐ | ☐ |
| 3. There are many places to go within easy walking distance of my home. | ☐ | ☐ | ☐ | ☐ |
| 4. It is easy to walk to a transit stop (bus, train) from my home. | ☐ | ☐ | ☐ | ☐ |

## C. Streets in my neighbourhood

**Please check the answer that best applies to you and your neighbourhood.**

| | Strongly disagree | Somewhat disagree | Somewhat Agree | Strongly Agree |
|---|---|---|---|---|
| 1. The distance between intersections in my neighbourhood is usually short (100 yards or less; the length of a football field of less) | ☐ | ☐ | ☐ | ☐ |
| 2. There are many four-way intersections in my neighbourhood. | ☐ | ☐ | ☐ | ☐ |
| 3. There are many alternative routes for getting from place to place in my neighbourhood. (I don't have to go the same way every time.) | ☐ | ☐ | ☐ | ☐ |

## D. Places for walking and cycling

**Please check the answer that best applies to you and your neighbourhood.**

| | Strongly disagree | Somewhat disagree | Somewhat Agree | Strongly Agree |
|---|---|---|---|---|
| 1. There are sidewalks on most of the streets in my neighbourhood. | ☐ | ☐ | ☐ | ☐ |
| 2. The sidewalks in my neighbourhood are well maintained (paved, even, and not a lot of cracks) | ☐ | ☐ | ☐ | ☐ |
| 3. There is a grass/dirt strip that separates the streets from the sidewalks in my neighbourhood. | ☐ | ☐ | ☐ | ☐ |

**Household ID**

☐☐ ☐☐☐ ☐☐☐

*Centre #* *Community #* *Household #*

**Subject Initials** ☐☐☐
*F M L*

## E. Neighbourhood surroundings

**Please check the answer that best applies to you and your neighbourhood.**

| | Strongly disagree | Somewhat disagree | Somewhat Agree | Strongly Agree |
|---|---|---|---|---|
| 1. Trees give shade for the sidewalks in my neighbourhood. | ☐ | ☐ | ☐ | ☐ |
| 2. There are many interesting things to look at while walking in my neighbourhood. | ☐ | ☐ | ☐ | ☐ |
| 3. My neighbourhood is generally free from litter. | ☐ | ☐ | ☐ | ☐ |

## F. Safety from traffic

**Please check the answer that best applies to you and your neighbourhood.**

| | Strongly disagree | Somewhat disagree | Somewhat Agree | Strongly Agree |
|---|---|---|---|---|
| 1. There is so much traffic along the street I live on that it makes it difficult or unpleasant to walk in my neighbourhood. | ☐ | ☐ | ☐ | ☐ |
| 2. There is so much traffic along nearby streets that it makes it difficult or unpleasant to walk in my neighbourhood. | ☐ | ☐ | ☐ | ☐ |
| 3. The crosswalks in my neighbourhood help walkers feel safe crossing busy streets. | ☐ | ☐ | ☐ | ☐ |

## G. Safety from crime

**Please check the answer that best applies to you and your neighbourhood.**

| | Strongly disagree | Somewhat disagree | Somewhat Agree | Strongly Agree |
|---|---|---|---|---|
| 1. My neighbourhood streets are well lit at night | ☐ | ☐ | ☐ | ☐ |
| 2. The crime rate in my neighbourhood makes it unsafe to go on walks during the day. | ☐ | ☐ | ☐ | ☐ |
| 3. The crime rate in my neighbourhood makes it unsafe to go on walks at night. | ☐ | ☐ | ☐ | ☐ |

**Household ID**

| | | |
|---|---|---|
| Centre # | Community # | Household # |

**Subject Initials** F M L

## H. Neighbourhood satisfaction

**Below are things about your neighbourhood with which you may or may not be satisfied. Please indicate your satisfaction by checking the appropriate box for that item. Please be open and honest in your responding.**

| | Strongly dissatisfied | Somewhat dissatisfied | Neither satisfied or dissatisfied | Somewhat satisfied | Strongly satisfied |
|---|---|---|---|---|---|
| a) the access to public transportation in your neighbourhood? | ☐ | ☐ | ☐ | ☐ | ☐ |
| b) your commuting time to work/school? | ☐ | ☐ | ☐ | ☐ | ☐ |
| c) the access to shopping in your neighbourhood? | ☐ | ☐ | ☐ | ☐ | ☐ |
| d) the number of people you know in your neighbourhood? | ☐ | ☐ | ☐ | ☐ | ☐ |
| e) how easy and pleasant it is to walk in your neighbourhood? | ☐ | ☐ | ☐ | ☐ | ☐ |
| f) access to entertainment in your neighbourhood(restaurants, movies, clubs, etc.)? | ☐ | ☐ | ☐ | ☐ | ☐ |
| g) the safety from threat of crime in your neighbourhood? | ☐ | ☐ | ☐ | ☐ | ☐ |
| h) the amount and speed of traffic in your neighbourhood? | ☐ | ☐ | ☐ | ☐ | ☐ |
| i) your neighbourhood as a good place to raise children? | ☐ | ☐ | ☐ | ☐ | ☐ |
| j) your neighbourhood as a good place to live? | ☐ | ☐ | ☐ | ☐ | ☐ |

*Appendix VI*

***International Physical Activity Questionnaire***

## PURE/South Africa

We are very grateful to you for your participation in this study. All information given by you will be held in strict confidence, and will be used for the purpose of this study only after removing any personal identifying information.

# Physical Activity Questionnaire

## INSTRUCTIONS

Please answer EACH question by marking an X in ONE BOX on each line:
(unless otherwise instructed)

[X]

OR

By writing number(s) in the spaces provided:

[1] [8]

OR

By specifying the answer on the line(s) provided

July, 2007

## Physical Activity Questionnaire

**Subject Initials- F=** first letter of first name
**M=** first letter of middle name
**L=** first letter of last name

**Subject ID**

☐☐ Centre # ☐☐☐ Community # ☐☐☐ Household # ☐☐ Subject #

**Subject Initials** ☐☐☐ *F M L*

**Today's date:** ☐☐☐☐ *year* ☐☐ *month* ☐☐ *day*

**1. During your working life, what has been or what was your main occupation?**

__________________________________________________

## Part 1: Job-related physical activity

(paid or unpaid jobs outside of the home) *Do not include house or yard work*

**2. Do you currently have a job or do any unpaid work outside your home?**

☐ No → **If no, Go to PART 2** ☐ Yes → **If yes, Go to question # 2**

**3. During the *last 7 days*, on how many days did you do *heavy* physical actitivies for at least 10 min (eg. heavy lifting, digging, heavy construction) as part of your work?**

☐ Days per week → Usual time spent on one of those days doing heavy physical activities at work ☐☐ hrs. ☐☐ min.

☐ No vigorous activity at work

**4. During the *last 7 days*, on how many days did you do *moderate* physical activities for at least 10 min (eg. carrying light loads) as part of your work?** *Please do not include walking*

☐ Days per week → Usual time spent on one of those days doing moderate physical activities at work ☐☐ hrs. ☐☐ min.

☐ No moderate activity at work

**5. During the *last 7 days*, on how many days did you *walk* for at least 10 min at a time as part of your work?** *Please do not count any walking you did to travel to or from work*

☐ Days per week → Usual time spent on one of those days walking at work ☐☐ hrs. ☐☐ min.

☐ No walking at work

**Subject ID**

☐☐ Centre # ☐☐☐ Community # ☐☐☐ Household # ☐☐ Subject #

**Subject Initials** ☐☐☐ F M L

## Part 2: Transportation related physical activity

**6. During the *last 7 days*, on how many days did you *travel in a motor vehicle* to places like work, stores, movies, and so on?**

☐ Days per week → Usual time spent on one of those days traveling in a motor vehicle ☐☐ hrs. ☐☐ min.

☐ No traveling in a motor vehicle

**7. During the *last 7 days*, on how many days did you *bicycle* for at least 10 minutes at a time to go from place to place?**

☐ Days per week → Usual time spent on one of those days bicycling from place to place ☐☐ hrs. ☐☐ min.

☐ No bicycling from place to place

**8. During the *last 7 days*, on how many days did you *walk* for at least 10 min at a time to go from place to place?**

☐ Days per week → Usual time spent on one of those days walking from place to place ☐☐ hrs. ☐☐ min.

☐ No walking from place to place

**Subject ID**

☐☐ ☐☐☐ ☐☐☐ ☐☐
*Centre # Community # Household # Subject #*

**Subject Initials** ☐☐☐
*F M L*

## Part 3: Housework, house maintenance, and caring for family

**9. During the *last 7 days*, on how many days did you do *vigorous* physical activities for at least 10 min (eg. heavy lifting, chopping wood, shoveling snow or digging in the garden) in the garden or yard?**

☐ Days per week → Usual time spent on one of those days doing vigorous physical activities in the garden or yard ☐☐ hrs. ☐☐ min.

☐ No vigorous activity

**10. During the *last 7 days*, on how many days did you do *moderate* activities (eg. carrying light loads, sweeping, washing windows, and raking in the yard) in the garden or yard?**

☐ Days per week → Usual time spent on one of those days doing moderate physical activities in the garden or yard ☐☐ hrs. ☐☐ min.

☐ No moderate activity

**11. During the *last 7 days*, on how many days did you do *moderate* physical activities for at least 10 min (eg. carrying light loads, washing windows, scrubbing floors and sweeping) inside your home?**

☐ Days per week → Usual time spent on one of those days doing moderate physical activities inside the home ☐☐ hrs. ☐☐ min.

☐ No moderate activity inside the home

**Subject ID**

☐☐ Centre # ☐☐☐ Community # ☐☐☐ Household # ☐☐ Subject #

**Subject Initials** ☐☐☐ F M L

## Part 4: Recreation, sport, and leisure-time physical activity

**12. Not counting any walking you have already mentioned, during the *last 7 days*, on how many days did you *walk* for at least 10 minutes during in your leisure time?**

☐ Days per week → Usual time spent on one of those days walking in leisure time ☐☐ hrs. ☐☐ min.

☐ No walking in leisure time

**13. During the *last 7 days*, on how many days did you do *vigorous physical* activities (eg. aerobics, running, fast bicycling, or fast swimming) in your leisure time?**

☐ Days per week → Usual time spent on one of those days doing vigorous physical activities in leisure time ☐☐ hrs. ☐☐ min.

☐ No vigorous activity in leisure time

**14. During the *last 7 days*, on how many days did you do *moderate* physical activities for at least 10 min (eg. bicycling at a regular pace, swimming at a regular pace) in your leisure time**

☐ Days per week → Usual time spent on one of those days doing moderate physical activities in leisure time ☐☐ hrs. ☐☐ min.

☐ No moderate activity in leisure time

## Part 5: Time spent sitting

**15. During the *last 7 days*, how much time did you usually spend sitting on a *weekday*?**

☐☐ hrs. ☐☐ min.

**16. During the *last 7 days*, how much time did you usually spend sitting on a *weekend day*?**

☐☐ hrs. ☐☐ min.

**17. Name of Interviewer:** *(please print)* ______ *First Initial* ____________ *Last Name* **Interviewer code:** ☐☐☐

*Appendix VII*

***Flow Chart of included studies***

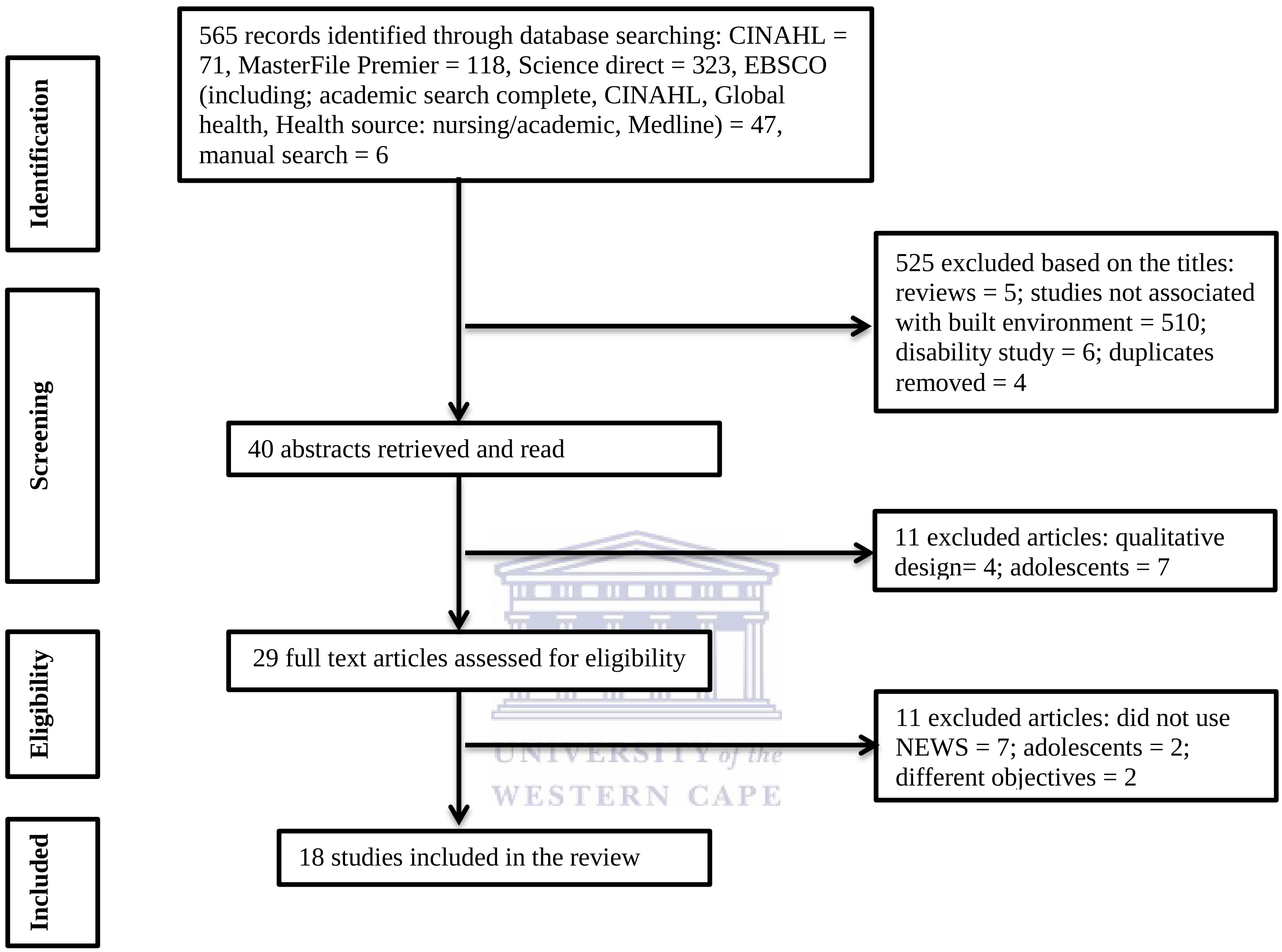


**Figure 2.1 This figure represents the flow of the literature review conducted according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines [16]**

*Appendix VIII*

*PRISMA 2009 Check List*

## Appendix, table 2 PRISMA 2009 Checklist

| Section/topic | # | Checklist item | Reported on page # |
|---|---|---|---|
| **TITLE** | | | |
| Title | 1 | Identify the report as a systematic review, meta-analysis, or both. | 1 |
| **ABSTRACT** | | | |
| Structured summary | 2 | Provide a structured summary including, as applicable: background; objectives; data sources; study eligibility criteria, participants, and interventions; study appraisal and synthesis methods; results; limitations; conclusions and implications of key findings; systematic review registration number. | 2-3 |
| **INTRODUCTION** | | | |
| Rationale | 3 | Describe the rationale for the review in the context of what is already known. | 3-4 |
| Objectives | 4 | Provide an explicit statement of questions being addressed with reference to participants, interventions, comparisons, outcomes, and study design (PICOS). | 3-4 |
| **METHODS** | | | |
| Protocol and registration | 5 | Indicate if a review protocol exists, if and where it can be accessed (e.g., Web address), and, if available, provide registration information including registration number. | NA |
| Eligibility criteria | 6 | Specify study characteristics (e.g., PICOS, length of follow-up) and report characteristics (e.g., years considered, language, publication status) used as criteria for eligibility, giving rationale. | 6 |
| Information sources | 7 | Describe all information sources (e.g., databases with dates of coverage, contact with study authors to identify additional studies) in the search and date last searched. | 4 |
| Search | 8 | Present full electronic search strategy for at least one database, including any limits used, such that it could be repeated. | 4-5 |
| Study selection | 9 | State the process for selecting studies (i.e., screening, eligibility, included in systematic review, and, if applicable, included in the meta-analysis). | 6 |
| Data collection process | 10 | Describe method of data extraction from reports (e.g., piloted forms, independently, in duplicate) and any processes for obtaining and confirming data from investigators. | 6-7 |
| Data items | 11 | List and define all variables for which data were sought (e.g., PICOS, funding sources) and any assumptions and simplifications made. | 4-5 |
| Risk of bias in individual studies | 12 | Describe methods used for assessing risk of bias of individual studies (including specification of whether this was done at the study or outcome level), and how this information is to be used in any data synthesis. | 7-8 |
| Summary measures | 13 | State the principal summary measures (e.g., risk ratio, difference in means). | NA |
| Synthesis of results | 14 | Describe the methods of handling data and combining results of studies, if done, including measures of consistency (e.g., $I^2$) for each meta-analysis. | NA |

## Appendix, table 2 PRISMA 2009 Checklist

| Section/topic | # | Checklist item | Reported on page # |
|---|---|---|---|
| Risk of bias across studies | 15 | Specify any assessment of risk of bias that may affect the cumulative evidence (e.g., publication bias, selective reporting within studies). | NA |
| Additional analyses | 16 | Describe methods of additional analyses (e.g., sensitivity or subgroup analyses, meta-regression), if done, indicating which were pre-specified. | NA |
| **RESULTS** | | | |
| Study selection | 17 | Give numbers of studies screened, assessed for eligibility, and included in the review, with reasons for exclusions at each stage, ideally with a flow diagram. | 8-10 (fig. 1) |
| Study characteristics | 18 | For each study, present characteristics for which data were extracted (e.g., study size, PICOS, follow-up period) and provide the citations. | 8-9 (table, 4) |
| Risk of bias within studies | 19 | Present data on risk of bias of each study and, if available, any outcome level assessment (see item 12). | NA |
| Results of individual studies | 20 | For all outcomes considered (benefits or harms), present, for each study: (a) simple summary data for each intervention group (b) effect estimates and confidence intervals, ideally with a forest plot. | 8-12 |
| Synthesis of results | 21 | Present results of each meta-analysis done, including confidence intervals and measures of consistency. | NA |
| Risk of bias across studies | 22 | Present results of any assessment of risk of bias across studies (see Item 15). | NA |
| Additional analysis | 23 | Give results of additional analyses, if done (e.g., sensitivity or subgroup analyses, meta-regression [see Item 16]). | NA |
| **DISCUSSION** | | | |
| Summary of evidence | 24 | Summarize the main findings including the strength of evidence for each main outcome; consider their relevance to key groups (e.g., healthcare providers, users, and policy makers). | 13-14 |
| Limitations | 25 | Discuss limitations at study and outcome level (e.g., risk of bias), and at review-level (e.g., incomplete retrieval of identified research, reporting bias). | 14-15 |
| Conclusions | 26 | Provide a general interpretation of the results in the context of other evidence, and implications for future research. | 15 |
| **FUNDING** | | | |
| Funding | 27 | Describe sources of funding for the systematic review and other support (e.g., supply of data); role of funders for the systematic review. | 16 (See financial disclosure/ funding) |

*From:* Moher D, Liberati A, Tetzlaff J, Altman DG, The PRISMA Group (2009). Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement. PLoS Med 6(7): e1000097. doi:10.1371/journal.pmed1000097

For more information, visit: www.prisma-statement.org

***Appendix XIX:***

***Table 2.4 Excluded Studies***

| Item # | Authors | Title | Reason (s) for exclusion |
|---|---|---|---|
| 01 | Nathan *et al*., 2012 [1] | The association between neighborhood greenness and cardiovascular disease: an observational study | The authors used Normalized Difference Vegetation Index (NDVI) instead of NEWS |
| 02 | Kim *et al*., 2014 [2] | Perceived neighborhood social cohesion and myocardial infarction | Perceived social environment variables was not part of the NEWS |
| 03 | Cunningham-Myrie *et al.*, 2014 [3] | Associations between neighborhood effects and physical activity, obesity, and diabetes: The Jamaica Health and Lifestyle Survey2008 | The age group did not meet the criteria for the review |
| 04 | Piccolo *et al.*, 2014 [4] | The role of neighborhood characteristics in racial/ethnic disparities in type 2 diabetes: Results from the Boston Area Community Health (BACH) Survey | Objective of the study did not met the criteria for the review |
| 05 | Hirsch *et al*., 2014 [5] | Change in Walking and Body Mass Index Following Residential Relocation: The Multi-Ethnic Study of Atherosclerosis | Walk Score index was used instead of NEWS |
| 06 | Fish *et al.*, 2010 [6] | Association of perceived neigborhood safety on body mass index | A survey question was not adopted from NEWS |
| 07 | James *et al.*, 2013 [7] | Urban Sprawl, Physical Activity, and Body Mass Index: Nurses' Health Study and Nurses' Health Study II | Sprawl index was used instead of the News |
| 08 | Drewnowski *et al.*, 2012 [8] | Obesity and Supermarket Access: Proximity or Price? | The characteristics of the independent variable (supermarkets) did not meet the criteria for the review |
| 09 | Casagrande *et al.*, 2011[9] | Association of Walkability With Obesity in Baltimore City, Maryland | The Pedestrian Environment Data Scan (PEDS)/ was a measure instead of the NEWS |
| 10 | Oyeyemi *et al.*, 2011[10] | Perceived environmental correlates of physical activity and walking in African young adults | The age group did not meet the criteria for the review |
| 11 | Powell-Willey *et al*., 2013 [11] | Relationship between Perceptions about Neighborhood Environment and Prevalent Obesity: Data from the Dallas Heart Study | Survey question not adopted from the NEWS |

*Appendix X:*

*Use of the ActiGraph Accelerometer*

**Dear Participants**

Please wear this hip monitor for 7 days from when you leave the UCT lab. During this time, please carry on with all your normal activities.

**Description:**
The hip monitor is a movement sensor and you should wear it all the time, except, when you are showering, bathing and swimming. Whenever you need to remove the sensor, please reattach it as soon as you can.
**Placement:**
Place the belt around your waist. Please, make sure that it is placed approximately on the centre of your right hip (see picture below).



Please, take care that the monitor sits snugly around your hip and that it is not too loose.
**Return:**
When you have completed your measurement, please return the monitor to Ms Nandipha Sinyana [Field Worker].

Thank you!

# Appendix XI

## *Publications*

CHAPTER 2

**Built Environment, Selected Risk Factors and Major Cardiovascular Disease Outcomes: A Systematic Review.**

PLOS | ONE

RESEARCH ARTICLE

# Built Environment, Selected Risk Factors and Major Cardiovascular Disease Outcomes: A Systematic Review

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## Abstract

### Introduction

Built environment attributes have been linked to cardiovascular disease (CVD) risk. Therefore, identifying built environment attributes that are associated with CVD risk is relevant for facilitating effective public health interventions.

### Objective

To conduct a systematic review of literature to examine the influence of built environmental attributes on CVD risks.

### Data Source

Multiple database searches including Science direct, CINAHL, Masterfile Premier, EBSCO and manual scan of reference lists were conducted.

### Inclusion Criteria

Studies published in English between 2005 and April 2015 were included if they assessed one or more of the neighborhood environmental attributes in relation with any major CVD outcomes and selected risk factors among adults.

### Data Extraction

Author(s), country/city, sex, age, sample size, study design, tool used to measure neighborhood environment, exposure and outcome assessments and associations were extracted from eligible studies.



**Citation:** Malambo P, Kengne AP, De Villiers A, Lambert EV, Puoane T (2016) Built Environment, Selected Risk Factors and Major Cardiovascular Disease Outcomes: A Systematic Review. PLoS ONE 11(11): e0166846. doi:10.1371/journal.pone.0166846

**Editor:** Carmine Pizzi, University of Bologna, ITALY

**Received:** June 9, 2016

**Accepted:** November 5, 2016

**Published:** November 23, 2016



**Data Availability Statement:** All relevant data are within the paper and its Supporting Information files.

**Funding:** The authors received no specific funding for this work.

**Competing Interests:** The authors have declared that no competing interests exist.

## Results

Eighteen studies met the inclusion criteria. Most studies used both cross-sectional design and Geographic Information System (GIS) to assess the neighborhood environmental attributes. Neighborhood environmental attributes were significantly associated with CVD risk and CVD outcomes in the expected direction. Residential density, safety from traffic, recreation facilities, street connectivity and high walkable environment were associated with physical activity. High walkable environment, fast food restaurants, supermarket/grocery stores were associated with blood pressure, body mass index, diabetes mellitus and metabolic syndrome. High density traffic, road proximity and fast food restaurants were associated with CVDs outcomes.

## Conclusion

This study confirms the relationship between neighborhood environment attributes and CVDs and risk factors. Prevention programs should account for neighborhood environmental attributes in the communities where people live.


## Background

Current global mortality rates from non-communicable diseases (NCDs) remain unacceptably high and are increasing [1]. More than 70% of global cardiovascular disease (CVD), are attributable to modifiable risk factors [2]. Rapidly globalization is accompanied by increasing urbanization, population growth and changes in demographics and promotes trends towards unhealthy lifestyles [3]. The ecological model, however, states that an individual's behaviour is influenced by multiple level factors such as social, neighborhood environment, and policy factors [4,5]. One of these factors, the neighborhood environment, and its link to health have been the focus of an increasing number of studies in recent years [6]. These studies are from a variety of disciplines, including urban planning and transportation planning [7].

Despite increases in the number of studies on the relationship between the neighborhood environment and health, the potential impact of the neighborhood environment across a range of health outcomes has not been fully explored. For instance, existing studies have focused on specific CVD risk factors such as obesity [7–9], metabolic syndrome [10], physical activity [11,12] and walking [13]. In addition, a recent study reviewed obesity-related outcomes [14]. Although Mayne et al. 2015[14] used quasi-experiment in their review, the study centered on obesity and related risk factors. Previously, the association between built environment and obesity has received wide publication. However, no study has broadly reviewed the relationship of neighborhood environment with major CVD outcomes and risk factors, while such a review is necessary to guide future research and policy formulation in this sector [15]. Therefore, the purpose of this study is to synthesize the studies on the association between a number of neighborhood environment attributes and CVD risks.

## Methodology

### Data sources/ search strategy

A comprehensive search was conducted to identify all research articles published from 2005 to 2015 that examine neighborhood environment, major CVD outcomes and selected risk factors (Table 1). English language articles were identified from the following databases: EBSCO (including: Academic Search, CINAHL, Global Health, Health Source: Nursing/academic and

Table 1. Database Search strategies.

| No | Search terms |
|---|---|
| **CINAHL** | |
| **No** | **Search terms** |
| 01 | Neighborhood environment |
| 02 | Physical activity |
| 03 | Adults |
| 04 | #1 and #2 and #3 |
| **Master File Premier** | |
| 01 | Built environment |
| 02 | Overweight or obesity |
| 03 | Adults |
| 04 | #1 and #2 and #3 |
| **Science Direct** | |
| 01 | Perceived built environment |
| 02 | Diabetes mellitus |
| 03 | Adults |
| 04 | #1 and #2 and #3 |
| **EBSCO host** (including; academic search complete, CINAHL, Global health, Health source: nursing/ academic, Medline) | |
| 01 | Perceived neighborhood environment |
| 02 | Hypertension |
| 03 | Adult |
| 04 | #1 and #2 and #3 |
| 05 | Perceived built environment |
| 06 | Diabetes mellitus |
| 07 | Adults |
| 08 | #5 and #6 and #7 |
| 09 | Land use mix diversity |
| 10 | Metabolic syndrome |
| 11 | Adults |
| 12 | #9 and #10 and #11 |
| 13 | Social environment |
| 14 | Myocardial infarction |
| 15 | adults |
| 16 | #13 and #14 and #15 |
| 17 | Perceived neighborhood environment |
| 18 | Coronary heart disease |
| 19 | adults |
| 20 | #17 and #18 and #adults |

doi:10.1371/journal.pone.0166846.t001

Medline) and Science Direct. Significant studies were identified using any of the following keywords: neighbourhood environment, perceived neighborhood environment, perceived built environment, land use mix diversity, physical activity, social environment, overweight or obesity, hypertension, diabetes mellitus, metabolic syndrome, coronary heart disease and myocardial infarction.

## Study selection

Titles and abstracts of all identified articles were assessed for their potential eligibility. Full texts of potentially eligible articles were then retrieved and their eligibility was verified against

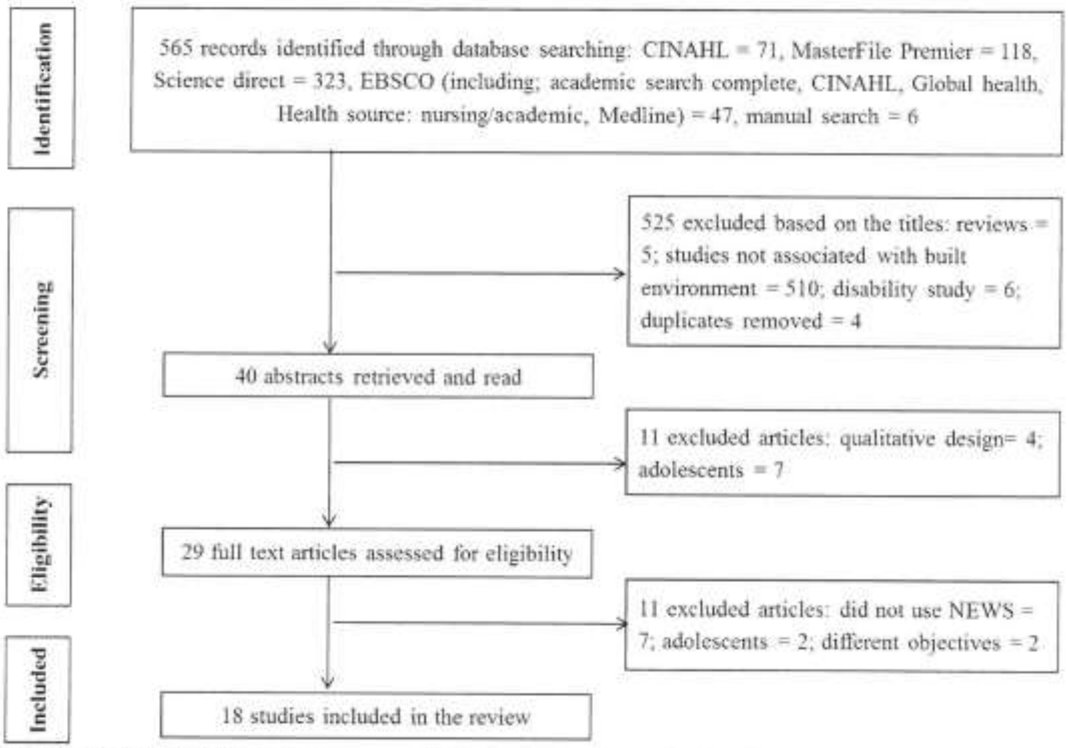


**Fig 1. Flow Chart of included studies.** This figure represents the flow of the literature review conducted according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines [16].

doi:10.1371/journal.pone.0166846.g001

the study eligibility criteria. Fig 1 (a flow chart of included studies; see appendix) represents the flow of the literature review conducted according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines [16], S1 Table (PRISMA 2009 checklist). Studies published in English were included if: 1) they used a Geographic Information System (GIS) [17] or subjectively assessed one or more of the built environment factors categorized according to the validated and reliably tested 'Neighborhood Environment Walkability Scale' (NEWS) which is a better questionnaire to assess the local environment [18]; 2) examined the relationship with any of the major CVD outcomes including myocardial infarction, coronary heart disease and stroke; 3) examined selected risk factors including physical activity (categorized in domains were considered), overweight or obesity, hypertension and diabetes mellitus; 4) were original reports on studies conducted among subjects aged 18 years and above; and 5) if the purpose of the studies were to explore the association between the variables of interest using multivariate analyses. Exclusion criteria were as follows: 1) Studies exclusively conducted on adolescents; 2) studies that employed a qualitative design; 3) systematic review papers; 4) publications from studies where subjects had difficulty with walking and 5) studies that did not meet the criteria for current review.

## Data extraction

The information extracted included the first authors' name, publication year, the sample size, gender, age range of the subjects, country and city where the study was conducted, study design, study tool (assess neighborhood environment), exposure assessment (any of the neighborhood environment attributes), outcome assessment (CVD outcomes or risk factors), and measures of association. Data abstraction, classification, and quality assessment of each study were conducted by two reviewers independently. A third reviewer was consulted if there was disagreement.

## Quality appraisal of the studies

In order to assess the methodological quality for each study selected, the 'Strengthening the reporting of observational studies in epidemiology' (STROBE) checklist [19] was adapted in accordance with the objectives of this study. For instance, this included the: sample size, setting, design, study tool (assessing neighborhood environment), exposure, outcome measure and association according to the area of this study. The final PRISMA checklist included 18 items that assessed the quality of this study. Each item scored one point if full reporting was met, or zero if not or partially reported.

## Data synthesis

Due to differences in research questions, exposure measurements, outcome measurements and methods across studies, a formal meta-analysis was not possible. Thus, the current review applied a semi-quantitative procedure [7]. The aim of this semi-quantitative procedure was to allow a rapid assessment of the strength of the evidence of an association between the exposure and the outcomes of interest by reducing a range of results from heterogeneous analytical designs to two binary questions [20]: a) did the study under review show a positive or negative association between the built environmental attributes and the outcome of interest? b) and, if so, was this finding statistically significant ($p<0.05$)? Hence, estimates of associations between neighborhood environment attributes, CVD risk factors and major outcomes were extracted from the eligible studies according to their substantive relevance and methodological findings and results summarized (Table 2). However, to take into account potential publication bias, we did not limit our analysis on papers published in peer-reviewed journals. References of finally included records were additionally checked. Built environment studies assessing relationship with CVD risks and outcomes are relatively recent. Therefore, this study restricted the search for a specific time period and database. Contrary, no quantitative assessment for risk of bias in individual studies was performed. However, in each study sample size, number of observations per built environment and total number of considered CVD risks and outcomes were checked, because small sample sizes result in biased effect estimates.

# Results

## Overview of the study selection process

An overview of the types of the articles selected is provided in Table 2, highlighting the author, country, gender, age, sample size, study design, study tools (assess neighborhood environment), exposure measures, outcome measures and their associations. The electronic search yielded 565 articles from the selected databases; MasterFile Premier = 118, CINAHL = 71, Science Direct = 323, EBSCO (including; Academic Search, CINAHL, Global Health, Health Source: Nursing/academic, and Medline) = 47, manual search = 6. After title/abstract screening, 525 articles were excluded for not meeting inclusion criteria. Of the excluded articles, 510

Table 2. Studies that have assessed neighborhood environmental attributes and CVD* risk factors and outcomes.

| | Research Methodology | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Author (s)/year | Country | Setting | Gender | Age | Sample | Study design | Tool | Exposure measure | Outcome measure | Association |
| Adams et al., 2012 [23] | USA | Urban | F | 66–77 | 368 (Baltimore) | C-S | NEWS | Land-use mix-diversity, access to services, infrastructure for walking/cycling, aesthetics, traffic safety, and crime safety | PA | Neighborhood attributes differed by as much as 10 minutes/day for moderate-to-vigorous PA, 1.1 hours/week for walking, and 50 minutes/week for leisure PA ($p \leq 0.001$). |
| | | | | | 360 (Seattle) | | | | BMI | BMI was lower in the high walkable/recreational dense neighborhoods ($p \leq 0.001$). |
| Witten et al., 2012 [24] | New Zealand | Urban | F/M | 20–65 | 2033 | C-S | GIS | Residential density, street connectivity, land use mix | PA | 1-SD increases in destination access, street connectivity, and dwelling density were associated with self-reported transport, leisure, or walking PA, with increased odds ranging from 21% (street connectivity with leisure PA, 95%-CI: 0%, 47%) to 44% (destination accessibility with walking, 95% CI: 17%, 79%). |
| Hanibuchi et al. 2011[33] | Japan | Urban/suburban/rural | F/M | 65+ | 9414 | C-S | GIS | Residential density, street connectivity, number of local destinations, access to recreational spaces, and land slope | Leisure time, sports activity and total walking time | Population density and presence of parks or green spaces had positive associations with PA |
| Heesch et al. 2014 [29] | Australia | Urban | F/M | 40–45 | 11036 | C-S | NEWS-A | Traffic volume, aesthetics, and crime, recreational facilities, traffic slowing device, cul-de-sacs, four-way intersections, hilly streets | Cycling | Perceived environmental attributes were positively associated with cycling ($p < 0.05$). |
| Wilson et al. 2011 [30] | Australia | Urban | F/M | 40–65 | 10286 | C-S | GIS | Public transport, shop, and park street lights, river or coast connectivity, residential density, hilliness, tree coverage, bikeways, and network distance to nearest river or coast, public transport, shop, and park. | Total Minutes walking in the past week | Walking was positively associated with connectivity, residential density, least tree coverage, bikeways and streetlights. |
| Martinez et al. 2012 [25] | USA | Community | F/M | 18–65 | 672 | C-S | NEWS | Neighborhood Safety (heavy traffic, crime, stray dogs, street lights and crosswalks); socio support | LTPA | Neighborhood attributes were negatively associated with meeting LTPA guidelines. |
| Zhou et al. 2013[37] | China | Schools | F/M | 40+ | 478 | C-S | NEWS-A | Residential density, diversity of land use, facility access, street connectivity, walking and cycling facilities, aesthetics, pedestrian safety, and crime safety | PA | Participants from downtown areas were more likely to engage in transportation related PA and leisure-time PA than respondents living in the suburbs. Residential density was positively associated with recreational or leisure-based PA. Street connectivity was negatively associated with leisure time PA. Moderate vigorous PA was negatively associated with traffic safety. Environmental attributes were not significantly associated with transportation PA. |
| Atkinson et al. 2005 [21] | USA | Urban | F/M | 20–65 | 102 | C-S | NEWS | Land-use mix-diversity, access to services, infrastructure for walking/cycling, aesthetics, traffic, safety, and crime safety | PA | Environment attributes were significantly associated with both vigorous-intensity self-reported and objectively measured physical activity. The vigorous and total activity accelerometer measures were correlated with street connectivity |

(Continued)

Table 2. (*Continued*)

| Author (s)/year | Country | Setting | Gender | Age | Sample | Study design | Tool | Exposure measure | Outcome measure | Association |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Research Methodology | | | | | | | | |
| Pruchno et al. 2014 [36] | USA | Community | F/M | 50–74 | 5688 | Survey | GIS | Supermarkets, grocery stores, local convenience stores, and fast-food restaurants | BMI | High densities of fast-food restaurants were positively associated with obesity. Supermarkets were not associated with obesity. |
| Drewnowski et al. 2012[26] | USA | Urban | F | 50–79 | 60775 | Survey | GIS | Density of grocery store and supermarkets and fast food restaurants (1.5 miles) | Blood Pressure | High densities of stores/supermarkets were associated with low diastolic blood pressure. |
| Li et al. 2009[31] | USA | Urban | F/M | 50–75 | 1145 | C-S | GIS | Land use mix, street connectivity, number of public transit stations, and amount of green and open spaces. Density of fast-food restaurants | Blood Pressure | High walkable neighborhoods were associated with decreased systolic and diastolic blood pressure. Neighborhoods of low walkability but with high density of fast-food restaurants were significantly associated with BP. The negative effect of fast-food restaurants on blood pressure was attenuated in high-walkable neighborhoods. |
| Baldock et al. 2012 [27] | Australia | Suburban | F/M | 18 + | 1324 | C-S | NEWS-AU | Land-use mix-diversity, access to services, infrastructure for walking/cycling, aesthetics, traffic safety, and crime safety | Metabolic syndrome | Metabolic syndrome was negatively associated with local land-use mix, positive aesthetics, and infrastructure for walking, and was positively associated with perceived crime and barriers to walking |
| Müller-Riemenschneider et al. 2013[34] | Australia | Rural | F/M | 25 + | 5970 | C-S | GIS | Residential density, street connectivity, land use mix | Metabolic syndrome. | High walkable neighborhoods were associated with low obesity and type-2 diabetes mellitus, but not with hypertension |
| Coffee et al. 2013 [32] | Australia | Urban | F/M | 18 + | 3593 | C-S | GIS | Walkability, index-dwelling density, intersection density, land-use mix and retail footprint | Metabolic syndrome | High walkability neighborhoods were associated with lower cardiometabolic risk. |
| Sundquist et al. 2014[33] | Sweden | Urban | F/M | 18 + | 512061 | Survey | GIS | Residential density, street connectivity, land use mix | Type 2 diabetes | Walkability was negatively associated with type 2 diabetes |
| Kan et al. 2008[35] | USA | Communities | F/M | 45–64 | 13309 | Survey | GIS | Traffic density/distance to major roads | CHD | High traffic density was positively associated with CHD |
| Hamano et al. 2013 [28] | Sweden | Urban | F/M | 35–80 | 4319674 | Longitudinal | GIS | Fast food restaurant, bars/pubs, PA and healthcare facilities | Stroke | High density fast food restaurants and pubs/bars were positively associated with stroke. Physical activity and healthcare facilities were negatively associated with stroke |
| Chum & O'Campo 2015[22] | Canada | Community | F/M | 25+ | 2411 | C-S | GIS | Violent crimes, environmental noise, and proximity to a major road, food, stores, parks/recreation, fast food restaurants | MI, angina, CHD, stroke, and CHF | High crime rate, environmental noise, and proximity to a major road were positively associated with increased CVDs. Reduced access to food stores, parks/recreation, and increased access to fast food restaurants were associated with increased CVDs. |

*CVD, cardiovascular disease; F, female; M, male; CS, cross-section; NEWS-AU, neighborhood environment walkability scale-Australia; PA, physical activity; BMI, body mass index; GIS, geographic information system; LTPA, leisure time physical activity; MI, myocardial infarction; CHD, Coronary heart disease; CHF; coronary heart failure.

doi:10.1371/journal.pone.0166846.t002

articles were unrelated to neighborhood environmental attributes, CVD risk and CVD outcomes, 5 were systematic reviews, 6 were conducted in a population with clinical conditions (disability), and another 4 were duplicates. The abstracts of 40 citations were then obtained and retrieved. Out of these abstracts, 11 were excluded since 4 were qualitative design and 7 were conducted among adolescents. Thus, 29 full text articles were assessed for eligibility. Of these, 11 were excluded as 7 did not use NEWS, 2 were conducted among adolescents and another 2 did not meet the objective of the review to measure BE (S2 Table, excluded articles). Therefore only 18 articles were finally eligible for inclusion in the current review. The flow chart in Fig 1 shows the process leading to the number of included articles for the review.

## General characteristics of the studies included

Table 2 depicts the descriptive characteristics of the included studies. The year of study ranged between 2005 [21] and 2015 [22], with 27.8% (n = 5) being published in 2012 [23–27]. Sample sizes varied across studies, ranging from 102 [21] to 4,319,674 [28]. In all, 55.5% (n = 10) of the studies were conducted in urban [21,23,24,26,28–32,33] areas as compared to rural [34], suburban [27] and urban/suburban/rural [35]. Community based studies [22,25,33,36] constituted 22.2% (n = 4) compared to one institution based study [37]. The reported ages of the participants ranged from 18 [25,27,32,33] to 80 years [28]. Most studies included females and males [21, 22,24,25,27–36] (88.9%; n = 16) with only 11.1% (n = 2) being in females only [23,26]. Sixteen studies (88.9%) were conducted in high-income countries [21–33,34, 36,38], 11.1% (n = 2) in middle income countries [35,37] and 38.9% (n = 7) were conducted in the USA alone [21,23,25,26,31,33,36]. Of all included studies, 94.4% (n = 17) were cross-sectional [21–22,26,27,29–38] with one being longitudinal [28].

## CVD risk factors and outcomes covered across studies

Of the 18 studies reviewed, 44.4% focused on physical activity [21,23–25,29,30,35,37], 16.7% on body mass index [23,35], 5.6% on blood pressure [26], 5.6% on diabetes mellitus [33] and 16.7% on metabolic syndrome [27,34,32]. Furthermore, 16.7% of studies [22,28,38] focused on coronary heart disease, stroke and heart failure, Table 2.

## Measurement of neighborhood environmental attributes

The majority of the studies (66.7%) used GIS [22,24,26,28,30–36] to assess neighbourhood environment attributes, while 33.3% used NEWS questionnaires [21,23,25,27,29,34] (Table 2).

## Association between neighborhood environment attributes and CVD risk

The majority of the reported associations of neighborhood environmental attributes with CVD risk factors and outcomes were statistically significant ($p < 0.05$) with effects estimates in the expected direction, and only two studies with mixed results, comparing neighborhood environmental attributes with transport related physical activity [37] and hypertension [34] respectively, reported no significant association, Table 2. Forty four percent of studies [21,23–25,29,30,35,37] reported variety of neighborhood environmental attributes associated with physical activity domains. Conversely, 11.1% of studies reported neighborhood environmental attributes were associated with body mass index [23,36] and blood pressure [26,31]. In addition, 16.6% studies reported metabolic syndrome [27, 32,34] and only one study indicated diabetes mellitus [33] to be related with Built environment attributes. Similarly, 16.6% of studies showed a significant association between neighborhood environmental attributes and myocardial infarction, coronary heart disease, congestive heart failure, angina and stroke [22, 28,38], Table 2.

## Discussion

This review has shown that a variety of neighborhood environmental attributes are associated with physical activity. Furthermore, density of fast food restaurants, supermarkets/grocery stores and high walkable neighborhood environments were associated with body mass index, blood pressure, diabetes mellitus and metabolic syndrome. In addition, high density traffic, road proximity and high density of fast food restaurants were associated with major CVD outcomes.

Our results are consistent with other studies [11,39]. In particular, physical activity was associated with safe footpaths and recreational facilities [40,41] and walking [42]. The results indicate that urban attributes such as street connectivity, residential density, recreational facilities and availability of traffic devices improves neighborhood walkability which may promote walking, leisure and transport related to physical activity which, consequently, lowers the incidence of CVDs. For instance, environmental attributes are thought to increase active transportation and lessen the need for private automobile use to accomplish daily tasks, which, in turn, lowers body mass index [43].

This review found that neighborhood environmental attributes such as fast-food restaurants and high walkable neighborhood environment were associated, either positively or negatively with body mass index, blood pressure and metabolic syndrome risk. Previous studies have reported similar results on the association between food environment and BMI [41,44,45] or blood pressure [10]. Greater accessibility to fast food restaurants may encourage people to make food choices at odds with 'healthy' dietary recommendations by making these choices easier [46]. Another explanation is that limited access to supermarkets may incentivize visits to convenience stores or fast food restaurants outlets [47] thereby increasing the chance of consuming unhealthy foods, with consequential increases in individual body mass indices and blood pressure levels.

Living in high walkable neighborhoods was associated with a lower prevalence of high body mass index, diabetes mellitus and metabolic syndrome risk. Similar results have been reported elsewhere [10]. Neighbourhood environmental attributes may increase an individual's active transportation related to the physical activity needed to accomplish daily tasks and thus lower the [43]. For example, a higher population density may support increased recreational opportunities and supermarkets offering a better supply of healthy foods, and so explaining associations between body mass index [48] and metabolic syndrome risk [10]. Moreover, high walkable neighborhood environments are associated with promoting recreational and transport related physical activity [49], participation in which eventually assists in lowering the prevalence of obesity or metabolic syndrome risks. Furthermore, an increase in intersection density in the neighborhood may promote walking through providing more route options and may regulate traffic [48].

Our study also observed that major CVD outcomes are related to built environment attributes. Specifically, a study has reported similar results on proximity to traffic [50]. Environmental attributes include proximity to stores, and access to supermarkets and non-fast food stores which may, consequently, affect the extent to which individuals walk and the food choices they make, which governs their diet and thus links to CVDs [51, 52]. Likewise, high traffic volumes have been associated with noise and air pollution which are linked to major CVDs. In addition, road proximity has been linked with low individual and neighborhood socioeconomic status, both of which have been shown to be associated with CVDs [53].

## Limitations of the review

One limitation of this study is the paucity of primary research on the association between neighborhood environmental attributes and CVD risk and major CVDs in an African context. Almost all publications included in the review were cross-sectional, thus causal inferences in the relationships could not be determined. The exclusion of studies not conducted in English also detracts from this study. In addition, this study reviewed few CVD risk factors with selected CVDs. Furthermore, we did not perform meta-analysis to derive pooled estimates of the association across studies. This was due to the much heterogeneity in measures of associations used across included studies, as well as the wide range of outcomes examined across studies. Future studies should explore any association between CVDs and other environmental attributes such as tobacco use, alcohol use and air pollution in order to have a broader understanding of other moderating effects. To our knowledge, this is the first review to document the associations between both objectively and subjectively measured built environment attributes and selected CVD risk and major CVDs. Methods of classification and categorization of the findings in this study follow those of other similar studies, facilitating comparisons. Moreover, this study further contributes to illustrating that studies from developed countries use comparable methodologies to studies from less well developed countries, such as this one.

## Conclusion

This study shows that both objective and perceived neighborhood environmental attributes are linked to CVD and its risk factors. The information gathered here from studies that explored neighborhood environmental attributes and their association with CVD risks and major CVD outcomes will help guide policy makers on the neighborhood environmental, transportation, health and education to improve intervention programs by local government and for people at a 'grass-roots' level. Future studies should further explore the associations of CVD risk and CVD outcomes with a broad set of neighborhood attributes using a longitudinal approach to better understand the direction of effects.

# Supporting Information

**S1 Table. PRISMA 2009-checklist.**
(DOC)

**S2 Table. Excluded full articles from the review.**
(DOCX)

# Acknowledgments

The authors would like to acknowledge South African Medical Research Council, Division of Exercise Science and Sports Medicine and School of Public Health for their material support in the study.

# Author Contributions

**Conceptualization:** PM APK.

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**Formal analysis:** PM.

**Funding acquisition:** TP EVL.

**Investigation:** PM.

**Methodology:** PM APK.

**Project administration:** PM.

**Supervision:** APK ADV EVL TP.

**Visualization:** PM APK.

**Writing – original draft:** PM APK.

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# CHAPTER 3

**Prevalence and socio-demographic correlates of physical activity levels among South African adults in Cape Town and Mount Frere communities in 2008-2009**

Malambo *et al. Archives of Public Health* (2016) 74:54
DOI 10.1186/s13690-016-0167-3

Archives of Public Health

RESEARCH Open Access

# Prevalence and socio-demographic correlates of physical activity levels among South African adults in Cape Town and Mount Frere communities in 2008-2009

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## Abstract

**Background:** Physical activity has been linked to reduced risk of various cardiometabolic disease, cancer, and premature mortality. We investigated the prevalence and socio-demographic correlates of physical activity among adults in urban and rural communities in South Africa. Methods: This was a cross-sectional survey comprising 1733 adults aged ≥35 years from the Cape Town (urban) and Mount Frere (rural) sites of the Prospective Urban Rural Epidemiology study. Physical activity was assessed using the validated International Physical Activity Questionnaire. Multinomial logistic regressions were used to relate physical activity with socio-demographic characteristics.

**Results:** Overall, 74% of participants engaged in moderate-to-vigorous physical activity. In the adjusted regression models, women were 34% less likely to engage in vigorous physical activity (OR =0.66, 95%-CI = 0.47-0.93). Physical activity decreased with age, varied with marital status, education and occupation, always in differential ways between urban and rural participants (all interactions $p \leq 0.047$). For instance, in urban settings, those with secondary education were more likely to engage in moderate physical activity (OR = 2.06, 95%-CI = 1.08-3.92) than those with tertiary education. Single people were more likely to engage in high physical activity (OR = 2.10, 95%-CI = 1.03-4.28) than divorced. Overall, skilled participants were more likely to engage in vigorous physical activity (OR = 2.07, 95%-CI = 1.41-3.05) driven by significant effect in rural area (OR = 2.70, 95%-CI = 1.51-4.83). Urban participants were more likely to engage in moderate physical activity (OR = 1.67, 95%-CI = 1.31-2.13) than rural participants.

**Conclusions:** To prevent chronic diseases among South Africans, attention should be paid to specific policies and interventions aimed at promoting PA among young adults in rural and urban setting, and across the social-economic diversity.

**Keywords:** Physical activity, Socio-demography, Determinants, Rural, Urban, Adult, Non-communicable diseases, South Africa

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## Background

The health benefits of physical activity (PA) in the prevention and control of non-communicable diseases (NCDs) are well established [1]. Participation rates in PA, however, remain low in all age groups [2]. For example, more than 60% of adults worldwide do not reach recommended 150 min weekly of moderate PA required to be of benefit to their health [3, 4]. It is estimated that physical inactivity defined as any activity insufficient to meet current global recommendations [5], indirectly causes 9% of premature mortality; it was linked to approximately 1.3 million of the 57 million deaths that occurred worldwide in 2008 [4]. For instance, physical inactivity could account for 6% of coronary heart disease, 7% of type 2 diabetes and 10% of cancer [4], making it the fourth leading cause of NCDs [3]. In South Africa, 3.3% of all deaths in 2000 were attributable to PA, ranking it 9$^{th}$ among other risk factors [6]. The prevalence of self-reported physical inactivity is high in both developed countries like the United States, where 32% of adults are physically inactive [7], and in developing countries such as South Africa were 45% adults were reported to be inactive [8]. Other African countries also report a high prevalence of physical inactivity among adults, 49.1% and 52.6% in Swaziland and Mauritania respectively [8].

Similar to other developing countries, South Africa is currently undergoing nutritional, lifestyle, and socioeconomic transitions, with increases in the occurrence of NCDs [9]. Non-communicable diseases of lifestyle share similar modifiable risk factors, which include hypertension, tobacco smoking, diabetes, obesity, hyperlipidaemia and physical inactivity [10]. Physically inactivity in global populations represents a major public health challenge [4]. Documented research comparing activity levels in urban and rural settings suggests that rural adults tend to be less active than their urban counterparts, although findings have been inconsistent [11]. In the USA, a study revealed that PA levels were higher in urban areas than in rural areas [12]. Similarly, in South Africa, subjects in isolated rural areas were found to be more inactive than their urban-dwelling counterparts [10]. Again, similar results were also reported in a study of Kenyan adolescents [13]. Conversely, a South African Demographic and Health Survey found that urban youths were more likely to be physically inactive than rural ones [14].

The importance of promoting physical activity in populations is reflected by the South Africa National Strategic Plan for the Prevention and Control of non-communicable diseases, which targets a 10% reduction in the prevalence of inactivity by 2020 [15]. Indeed, a recommendation for every adult to accumulate 30 min or more of moderate-intensity physical activity on as many days and, preferably, every day of the week [16] is estimated to increase the life expectancy of the world's population [4].

However, in order to understand PA patterns and make positive changes to them, it is important to understand the independent contributions of urban-rural and socio-demographic risk factors [17]. Conducting population-based studies on prevalence of physical activity and its determinants is necessary to identify the relevant areas in local environments that need change, areas where currently such information is scarce [18]. In this study, we determine the prevalence of self-reported PA and associated socio-demographic factors among South African adults in urban and rural communities.

## Methods

### Study population

This cross-sectional study uses data from the Cape Town (urban) and Mount-Frere (rural) sites of the global Prospective Urban and Rural Epidemiology study (PURE) study. PURE is a multinational cohort study that tracks societal influences, risk factors and chronic non-communicable diseases in urban and rural areas across 17 countries including South Africa. PURE collects baseline data on countries' characteristics (e.g. economic environment), communities (e.g. nutritional environment), households (e.g. income) and individual determinants (e.g. diet and physical activity) [19]. During a baseline evaluation conducted by PURE in 2008-2009, a representative random sample of adults was selected from well-established rural (Mount Frere) and urban (formal settlements in Cape Town) communities in South Africa. The household inclusion criteria were: (1) to have at least one member who was aged 35-70 years, (2) to be within an identified neighbourhood and (3) to not have members with a disability that precluded walking.

### Data collection

Participants were interviewed in the language of their choice. We used structured, socio-demographic and lifestyle questionnaires that were developed and standardized for the international PURE study [19]. Physical examination included anthropometric measures (height, weight, waist and hip circumference) [20]. In all consenting and eligible individuals, the long version of the International Physical Activity Questionnaire (IPAQ) was used to measure self-reported PA [21].

### Socio-demographic characteristics

We recorded socio-demographic information, specifically: age, sex, marital status, education level, and occupation from each participant. We grouped them into four age categories: 35 to 44 years, 45 to 54 years, 55 to 64 years and 65 years or older. Marital status was classified as never married, currently married, and widowed/divorced/separated. Education level was classified as primary, secondary and tertiary education. Occupational status ranged from 1 to 11 items prompted by the following statement; "*Please indicate which group best describes your main occupation*". In this study, the occupation status was then categorized as skilled (technicians, machine operators, clerks, skilled agriculture and fishery workers) and less skilled (homemaker, service, shop and market workers).

#### Physical activity measure

The IPAQ includes questions on frequency and duration of vigorous and moderate intensity physical activities, and walking in terms of the frequency (days/week) and duration (min/day) in the last 7 days. The physical activities were classified into the domains of work-related, transport-related, household-related and leisure activity for each category of walking, moderate and vigorous-intensity. Weekly minutes of walking, moderate-intensity and vigorous-intensity activity were calculated separately by multiplying the number of days/week by the duration on an average day. In this study, physical activity levels were classified as low, moderate, or high intensity, defined by the IPAQ core group (http://www.ipaq.ki.se) as follows: Low - no activity or some activity reported, but not enough to satisfy the requirements of the other activity categories; Moderate - any of the following 3 criteria: (a) 3 or more days of vigorous-intensity activity for at least 20 min per day, (b) 5 or more days of moderate intensity activity or waking for at least 30 min per day, or (c) 5 or more days of any combination of walking, moderate intensity, or vigorous-intensity activities achieving a minimum of 600 MET-minutes per week; Vigorous - either of the following 2 criteria: (a) 3 or more days of vigorous-intensity activity accumulating at least 1500 MET-minutes per week or (b) 7 days of any combination of walking or moderate- or vigorous intensity activities achieving a minimum of 3000 MET-minutes per week. Acceptable reliability and validity of IPAQ has been reported elsewhere [22].

#### Statistical analysis

The starting sample comprised 2064 participants of whom 316 were excluded for unacceptable levels of missing data [23]. A further 15 participants aged less than 35 years were excluded, making a final analytic sample of 1733 participants. We used SPSS® version 22 for Windows (IBM Corp: Armonk New York) for all statistical analyses. Chi squared tests were used to compare socio-demographic characteristics and physical activity. We used multinomial logistic regressions to investigate the determinants of physical activity, with low physical activity as the reference, both in univariate and multivariate models. The differential effects of socio-demographic characteristics on physical activity levels according to urban and rural setting were assessed through interaction tests. Statistical significance was set at $p < 0.05$.

## Results

#### General characteristics and pattern of physical activity

Table 1 shows the overall and site-specific (urban/rural), socio-demographic characteristics and the prevalence of

**Table 1** Socio-demographic characteristics of adults South Africans from Cape Town and Mount Frere communities in 2008-2009

| Variables | Urban ($n = 877$) (%) | Rural ($n = 856$) (%) | P-value | Overall ($N = 1733$) (%) |
|---|---|---|---|---|
| Gender | | | 0.011 | |
| Female | 71.4 | 76.8 | | 74.0 |
| Male | 28.6 | 23.2 | | 26.0 |
| Age | | | 0.375 | |
| 35-44 | 30.1 | 31.5 | | 30.8 |
| 45-54 | 35.0 | 31.1 | | 33.1 |
| 55-64 | 26.0 | 27.6 | | 26.8 |
| 65 and above | 8.9 | 9.8 | | 9.3 |
| BMI (kg/m²) | | | <0.001 | |
| < 18.5 | 3.7 | 2.8 | | 3.2 |
| 18.5-24.9 | 21.1 | 28.2 | | 25.3 |
| 25.0-29.9 | 18.2 | 27.3 | | 23.6 |
| > 30.0 | 57.0 | 41.7 | | 47.9 |
| Education level | | | <0.001 | |
| Primary | 23.8 | 49.9 | | 36.7 |
| Secondary | 69.1 | 47.3 | | 58.3 |
| Tertiary | 7.1 | 2.8 | | 5.0 |
| Marital status | | | <0.001 | |
| Single | 51.2 | 30.8 | | 41.1 |
| Currently married | 33.6 | 44.7 | | 39.1 |
| Widowed/divorced/separated | 15.2 | 24.4 | | 19.7 |
| Occupation | | | <0.001 | |
| Skilled | 22.2 | 14.6 | | 18.5 |
| Less skilled | 77.8 | 85.4 | | 81.5 |
| Ethnicity | | | 0.693 | |
| African | 98.7 | 98.9 | | 98.8 |
| Coloured | 1.3 | 1.1 | | 1.2 |
| Physical activity levels | | | <0.001 | |
| Low | 20.9 | 31.0 | | 25.9 |
| Moderate | 61.2 | 51.5 | | 56.4 |
| Vigorous | 17.9 | 17.5 | | 17.7 |

PA among the participants. Participants were evenly divided between urban (50.6%) and rural (49.4%) sites. Women comprised the majority of the sample in rural (76.8%) and urban (71.4%) sites and overall (74%) and their proportional was significantly higher than that of men ($p = 0.011$). The most common age group was 45-54 years (33.1%), and age distribution did not differ across sites ($p = 0.375$). Obesity (BMI ≥ 30 kg/m$^2$) was higher in the urban site at 57%, versus 42% in the rural site and differences were significant ($p < 0.001$). There were significant differences between urban and rural sites for categories of education, marital status and occupation (all $p < 0.001$), Table 1. Patterns of PA were 31%, 51.5% and 17.5% in the rural site; 20.9%, 61.2% and 17.9% in the urban site and 25.9%, 56.4% and 17.7% in combined sites for low, moderate and vigorous PA respectively in each case, and differences between sites were significant ($p < 0.001$), Table 1.

### Socio-demographic characteristics and physical activity levels

Table 2 shows the PA patterns for each socio-demographic category. Overall, gender, age, education level, marital status, occupation and location were significantly associated with physical activity ($p < 0.01$). In stratified analysis, the pattern of PA differed between men and women in the rural site ($p = 0.031$), but not the urban site ($p = 0.371$). The prevalence of vigorous physical activity decreased with increased age group in rural area ($p < 0.001$), and a borderline difference in the

**Table 2** Socio-demographic characteristics by physical activity levels among adults South Africans from Cape Town and Mount Frere communities in 2008-2009

| Variables | Urban ($n$ = 877) Physical activity | | | | Rural ($n$ = 856) Physical activity | | | | Overall ($N$ = 1733) Physical activity | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Low (%) | Moderate (%) | Vigorous (%) | $P$-value | Low (%) | Moderate (%) | Vigorous (%) | $P$-value | Low (%) | Moderate (%) | Vigorous (%) | $P$-value |
| Gender | | | | 0.371 | | | | 0.031 | | | | 0.014 |
| Women | 21.4 | 61.8 | 16.8 | | 32.1 | 52.2 | 15.7 | | 26.9 | 56.9 | 16.2 | |
| Men | 19.5 | 59.8 | 20.7 | | 27.1 | 49.2 | 23.6 | | 22.9 | 55.1 | 22.0 | |
| Age | | | | 0.057 | | | | <0.001 | | | | <0.001 |
| 35-44 | 20.5 | 62.1 | 17.4 | | 25.6 | 48.8 | 25.6 | | 23.0 | 55.4 | 21.5 | |
| 45-54 | 19.9 | 59.0 | 21.2 | | 27.1 | 57.1 | 15.8 | | 23.2 | 58.1 | 18.7 | |
| 55-64 | 18.9 | 63.6 | 17.5 | | 33.1 | 53.0 | 14.0 | | 26.1 | 58.2 | 15.7 | |
| 65 and above | 32.1 | 60.3 | 7.7 | | 54.8 | 38.1 | 7.1 | | 43.8 | 48.8 | 7.4 | |
| BMI (kg/m$^2$) | | | | 0.850 | | | | 0.314 | | | | 0.463 |
| < 18.5 | 29.4 | 52.4 | 17.6 | | 21.1 | 63.0 | 15.9 | | 25.0 | 58.3 | 16.7 | |
| 18.5-24.9 | 20.8 | 57.3 | 21.9 | | 29.5 | 52.6 | 17.9 | | 26.6 | 54.2 | 19.2 | |
| 25.0-29.9 | 20.5 | 61.4 | 18.1 | | 33.7 | 55.4 | 10.9 | | 29.6 | 57.3 | 13.1 | |
| > 30.0 | 17.3 | 63.5 | 19.2 | | 32.4 | 49.1 | 18.5 | | 25.1 | 56.0 | 18.9 | |
| Education level | | | | 0.009 | | | | 0.167 | | | | 0.003 |
| Primary | 24.4 | 63.6 | 12.0 | | 33.5 | 50.8 | 15.7 | | 30.5 | 55.0 | 14.5 | |
| Secondary | 18.6 | 61.9 | 19.5 | | 29.4 | 51.6 | 19.0 | | 22.9 | 53.8 | 19.3 | |
| Tertiary | 30.6 | 46.8 | 22.6 | | 12.5 | 62.5 | 25.0 | | 25.6 | 51.2 | 23.3 | |
| Marital status | | | | 0.010 | | | | 0.086 | | | | <0.001 |
| Single | 17.1 | 61.7 | 21.2 | | 28.8 | 51.1 | 20.1 | | 21.5 | 57.8 | 20.8 | |
| Married | 23.1 | 61.7 | 15.3 | | 29.2 | 52.0 | 18.8 | | 26.5 | 56.2 | 17.3 | |
| Divorced/separated | 28.6 | 58.6 | 12.8 | | 36.8 | 51.2 | 12.0 | | 33.6 | 54.1 | 12.3 | |
| Occupation | | | | <0.001 | | | | <0.001 | | | | <0.001 |
| Skilled | 21.0 | 51.8 | 27.2 | | 20.0 | 48.0 | 32.0 | | 20.6 | 50.3 | 29.1 | |
| Less skilled | 20.8 | 63.9 | 15.2 | | 32.8 | 52.1 | 15.0 | | 27.0 | 57.8 | 15.1 | |
| Location | | | | | | | | | | | | <0.001 |
| Urban | | | | | | | | | 20.9 | 61.2 | 17.9 | |
| Rural | | | | | | | | | 31.0 | 51.5 | 17.5 | |

distribution of PA across age groups in the urban site ($p$ = 0.057). Education levels in urban area was positively associated with vigorous PA ($p$ = 0.009), but not in the rural one ($p$ = 0.161). This pattern was different for marital status in the urban site ($p$ = 0.010), but not in the rural site ($p$ = 0.086). The pattern with occupation was mostly similar and differences were significant when stratified by site ($p$ < 0.001 in both sites), Table 2.

#### Multivariable regression analysis and interaction tests

Table 3 shows odds ratios from age and sex-adjusted multinomial regression analyses of socio-demographic characteristics and PA. In these models, when applied to all participants, age ($p$ < 0.001), occupation ($p$ < 0.001),) and location ($p$ < 0.001) were significantly associated with PA level, while there was a borderline association with gender ($p$ = 0.055), and no association with education ($p$ = 0.116) or marital status ($p$ = 0.126), Table 3. With the exception of gender ($p$ = 0.072), significant interactions were observed between location and socio-demographic characteristics (results not shown in the table), in their relationship with PA ($p$ < 0.001 for age*location, $p$ = 0.012 for education level*location, $p$ < 0.001 for marital status*location, $p$ < 0.001 for occupation*location interaction tests).

Overall, women were 34% less likely (OR = 0.66, 95%-CI = 0.47-0.95) to engage in vigorous PA than men. The odds of engaging in vigorous PA decreased with increasing age, with the effects being significant across age strata overall and in urban and rural participants. Each age category was more likely to engage in moderate and vigorous PA than those in the category aged 65 and above, in both the overall cohort and in rural participants, but not in the urban ones ($p$ < 0.001 for age*location interaction). Having a secondary education (relative to tertiary) was associated with an OR of 2.06 (95% CI = 1.08-3.92) for engaging in moderate PA among urban participants only.

Marital status was variably associated with PA in the overall cohort and across sites ($p$ < 0.001 for the interaction marital status*location). For instance, single participants (relative to those divorced) were more likely to engage in vigorous PA in the overall cohort and in the urban site, Table 3.

In the overall cohort, skilled participants (relative to less skilled) were associated with higher odds of engaging in vigorous PA. The effect was similar in both rural and urban participants ($p$ < 0.001 for occupation*-location interaction).

## Discussion

This study provides insight into the socio-demographic correlates of PA levels in the urban and rural communities of South African adults. Over half the participants sampled engaged in moderate to high PA. However, a higher proportion of physical inactivity was observed in the rural participants compared to those in urban areas. Urban participants were more likely to meet recommended PA guidelines for public health than their rural counterparts. Similarly, the odds of participants achieving recommended PA guidelines (moderate PA) were 76% higher in an urban than in a rural setting. The results of this study can be compared with the findings of a PA survey from 22 African countries where prevalence of PA ranged from 72.5% (Swaziland) to 96.0% (Mozambique) [8]. Similarly, 67% of urban dwelling black South African women were classified as physically active [24]. Conversely, the odds of participants being physically inactive in United States was 43% higher in the extreme rural areas compared with urban ones [12]. A study in Cameroon, however, showed that rural dwellers were significantly more active than their urban counterparts based on objectively measured physical activity [25].

A high prevalence of physical inactivity in rural areas, especially in South Africa, may be because PA is largely of low intensity there. A study conducted in KwaZulu-Natal in South Africa reported high volumes of low intensity physical activity among rural children and adolescents [26]. It is also stated that the spread of technology used across different domains of society and the shift in the predominant type of employment and lifestyle behaviour, specifically from agriculture to industries and services, contributed to a reduction in physical activity [27]. The variations of results across studies could be due to different tools used to measure physical activity. In addition, there is difficulty to understand the intent of the IPAQ questions, in recalling the information requested, and in making the calculations required to perform physical activity [28]. Furthermore, different types of PA are undertaken between and within communities that are socially, economically, geographically and religiously different across aspects of life [29]. For this reason, objective assessment of physical activity would provide more insight in the levels and patterns of physical activity in South African population. Therefore, results of the current study are interpreted with caution.

The overall prevalence of moderate to vigorous physical activity did not differ significantly between genders. However, the adjusted odds ratio showed that women were 34% less likely to engage in the vigorous PA than men. A similar study found that women exhibited higher levels of inactivity than men and that inactivity was higher among older people [8]. Concurrently, a study conducted in Spain reported comparable results [30]. Conversely, studies conducted in Rwanda [31] and Nigeria [17], showed a higher prevalence of PA among women than in men.

**Table 3** Multinomial logistic regression result of socio-demographic characteristics by physical activity levels with reference to low physical activity in adults South Africans from Cape Town and Mount Frere communities in 2008-2009

| Variables | Urban (n = 877) Physical activity | | | | p-value | Rural (n = 856) Physical activity | | | | p-value | Overall (N = 1733) Physical activity | | | | p-value |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Moderate | | Vigorous | | | Moderate | | Vigorous | | | Moderate | | Vigorous | | |
| | OR[a] | 95%-CI | OR[a] | 95%-CI | | OR[a] | 95%-CI | OR[a] | 95%-CI | | OR[a] | 95%-CI | OR[a] | 95%-CI | |
| Gender | | | | | 0.251 | | | | | 0.154 | | | | | **0.050** |
| Men | 1.00 | | 1.00 | | | 1.00 | | 1.00 | | | 1.00 | | 1.00 | | |
| Women | 0.89 | 0.61-1.32 | 0.71 | 0.44-1.14 | | 0.91 | 0.82-1.35 | **0.63** | 0.38-1.01 | | 0.91 | 0.69-1.19 | **0.66*** | 0.47-0.93 | |
| Age | | | | | 0.360 | | | | | **<0.001** | | | | | **<0.001** |
| 65 and above | 1.00 | | 1.00 | | | 1.00 | | 1.00 | | | 1.00 | | 1.00 | 2.07-8.13 | |
| 35-44 | 1.40 | 0.75-2.61 | 2.31 | 0.83-6.44 | | **2.66***** | 1.53-4.64 | **6.12***** | 2.40-15.62 | | **2.03***** | 1.36-3.05 | **4.06***** | 2.05-8.05 | |
| 45-54 | 1.31 | 0.70-2.48 | 2.47 | 0.88-6.94 | | **2.89***** | 1.65-5.09 | **3.29*** | 1.24-8.70 | | **2.01***** | 1.33-3.03 | **3.12***** | 1.59-6.28 | |
| 55-64 | 1.69 | 0.91-3.12 | **3.12*** | 1.13-8.60 | | **2.26**** | 1.32-3.88 | **2.98*** | 1.15-7.75 | | **1.98***** | 1.34-2.98 | **3.00***** | 1.49-6.103 | |
| Education level | | | | | 0.072 | | | | | 0.282 | | | | | 0.116 |
| Tertiary | 1.00 | | 1.00 | | | 1.00 | | 1.00 | | | 1.00 | | 1.00 | | |
| Primary | 1.68 | 0.82-5.42 | 1.06 | 0.43-2.64 | | 0.42 | 0.11-1.56 | 0.54 | 0.12-2.45 | | 1.26 | 0.70-2.27 | 1.05 | 0.51-2.15 | |
| Secondary | **2.06*** | 1.08-3.92 | 1.87 | 0.85-4.08 | | 0.44 | 0.12-1.68 | 0.63 | 0.14-2.75 | | 1.43 | 0.82-2.51 | 1.48 | 0.76-2.81 | |
| Marital status | | | | | **0.041** | | | | | 0.787 | | | | | 0.126 |
| Divorced | 1.00 | | 1.00 | | | 1.00 | | 1.00 | | | 1.00 | | 1.00 | | |
| Single | **1.66** | 0.99-2.78 | **2.10*** | 1.03-4.28 | | 0.95 | 0.60-1.50 | 1.35 | 0.72-2.53 | | 1.23 | 0.88-1.72 | **1.69*** | 1.06-2.69 | |
| Married | 1.24 | 0.74-2.07 | 1.09 | 0.53-2.28 | | 1.03 | 0.68-1.53 | 1.28 | 0.72-2.30 | | 1.10 | 0.81-1.51 | 1.20 | 0.77-1.88 | |
| Occupation | | | | | **<0.001** | | | | | **<0.001** | | | | | **<0.001** |
| Less skilled | 1.00 | | 1.00 | | | 1.00 | | 1.00 | | | 1.00 | | 1.00 | | |
| Skilled | 0.84 | 0.54-1.32 | **1.69*** | 1.00-2.85 | | 1.23 | 0.73-2.06 | **2.70***** | 1.51-4.83 | | 0.99 | 0.71-1.39 | **2.07***** | 1.43-3.03 | |
| Location | | | | | | | | | | | | | | | **<0.001** |
| Rural | | | | | | | | | | | 1.00 | | 1.00 | | |
| Urban | | | | | | | | | | | **1.67***** | 1.31-2.13 | 1.20 | 0.87-1.65 | |

OR odds ratios, CI confidence interval; *p < 0.05; **p < 0.01; ***p < 0.001; [a] Odds ratios adjusted for all variables in the table; bold p = significant borderline

Although it is difficult to interpret these conflicting results, South Africa could be described as a country in transition, and consequently there are currently high levels of infrastructure development, for which men are typically employed and often requires high levels of vigorous activity. Similarly, African cultural influence may make women more likely to be employed in domestic work such as cleaning and organizing households, which may mean they walk less, particularly in black townships areas [32]. Generally in African culture, women have hobbies that tend to keep them at home while men tend to engage in more physical recreational activities [32]. Based on these cultural differences, physical inactivity poses a major health risk to the South African women and with the projected increase in health risk to over 65 s, an increase in morbidity and mortality in these areas is expected. Hence, necessary interventions need to be implemented, among women through all age groups at societal level [33].

Our study showed that PA decreased with age, in accordance with previous studies [34, 35]. A similar study found that the volume of sedentary behaviour increased, whereas ambulatory activity [36] and recreational activity [37] decreased with age. Due to the fact that studies use different measures and definitions, direct comparisons are not possible. For example, vigorous activity have been reported to decrease with age, whereas moderate intensity activity increase from ages 13 to 27 years [38]. Furthermore, the relationship can be affected by the effect of various confounding factors such as genetic, cultural, socio-economic, nutritional factors and inactivity [39]. These act through reduction of the functional abilities, strength, and ambulation associated with increased age-related diseases. As a result, the relationship between physical activity and healthy ageing among adults still remains complex, and physical activity levels must be taken into account in ageing studies [39].

Level of education has also been associated with PA [40]. Similarly, results in this study showed that in urban areas, participants who had reached secondary level education were twice more likely to engage in moderate PA than those with tertiary education. In rural areas, participants with primary education tended to be the least likely group to engage in moderate PA. These results are comparable to another study which found the level of education was associated with the likelihood of walking [41]. Thus, people with less education may be more likely to walk or cycle than the highly educated, possibly because the latter may own a car, with the associated reduction in physical inactivity. It is also likely that less well educated people may be employed in jobs that are more physically demanding, while they also have insufficient money and time to engage in leisure-time PA. Contrarily, people at a higher educational level may have more sedentary jobs, but may engage more in leisure-time PA that those less well educated because they are more aware of it and its associated health benefits [42].

Cross-sectional studies report mixed results concerning the relationship between marital status and PA, although it is often an inverse relationship, where married individuals are less physically active than those who are unmarried [43]. This study showed that, both in the urban site and overall, a higher proportion of single participants engaged in moderate-to-vigorous PA than those who were divorced or separated, and comparable results to these were reported by a study in Lebanon [44]. There are however also reports that show married people as being more active than the single people [45], and a study based in Nigeria found a positive association between being married and reaching sufficient PA levels [18]. However, in this study, being married was not a determinant factor for PA.

Contrasting results in studies of the relationship between marital status and PA could be a consequence of contrasting variables. For instance, cultural expectations of married African adults, especially men, may differ and men may be expected to be the primary earners [18] but this may not be true in all countries, such as South Africa.

Likewise, this study noted that participants with skilled jobs were more likely to engage in vigorous PA than less skilled (or homemakers). Similarly, a study in Mexico showed that a higher percentage of adults working in agriculture and fishing were in a higher activity level category than those in lower-intensity occupational activities, the latter also having a greater proportion of participants in low and moderate activity levels [46]. A study in Australia, however, showed those participants in the lower strata of occupations to be less likely to report participation in vigorous PA sufficient to achieve cardiorespiratory fitness [47]. Most of sub-Saharan African countries, particularly those undergoing rapid developments, are in the midst of demographic and epidemiologic transitions. These developmental processes bring about changes in the social capital of societies, change working patterns and lifestyles contributing to reduction in physical activity levels [48].

#### Limitations and strengths

Our study has some limitations. Its cross-sectional design did not allow for the investigation of causal relationship among characteristics. This study was restricted to adults only, in two provinces of South Africa, and its findings may not be applicable countrywide. Finally, another limiting factor of this study was that PA was assessed with a version of IPAQ, a self-report measure associated with overestimation of PA levels [45]. Nevertheless, this study was based on a large cohort of urban and rural South Africans, primarily of African descent which was assessed using a standardized method for surveying risk factors for chronic diseases. The study adds to previous reports by providing determinants and prevalence of PA levels in an urban and rural setting in South Africa. However, future studies aiming at monitoring of the exposure to PA should consider conducting objective assessment of PA in order to validate PA in urban and rural communities.

## Conclusion

Culturally or community tailored intervention to promote physical activity should target individuals at an early age, those with primary, tertiary education, married and divorced and rural residents in South Africa. The current study indicates that if no effective public health approach or social economic plans are implemented, further decrease in physical activity will lead to high risk of developing major chronic diseases among South Africans. Studies using objective assessment of physical activity are needed to confirm these findings.

#### Abbreviations

BMI: Body mass index; IPAQ: International Physical Activity Questionnaire; METs: Metabolic rate; NCDs: Non-communicable diseases; PA: Physical activity; PHRI: Population Health Research Institute; PURE: Prospective Urban and Rural epidemiology study; USA: United Sates of America; UWC: University of the Western Cape

#### Acknowledgements

The author gratefully acknowledges the Population Health Research Institute, Hamilton Health Sciences and McMaster University, Hamilton Canada and the South African Medical Research Council for providing access to these data. Opinions, findings, conclusions and recommendations expressed are those of the authors and the funders accept no liability whatsoever in this regard.

#### Funding

This study was partially supported by Social Innovation in Public Health Impulse fellowship programme for analysis, interpretation of data, transport and accommodation.

#### Availability of data and materials

Please contact author for data requests.

#### Authors' contributions

PM, APK and EVL were involved in the conception and design. PM conducted the analysis. PM and APK were involved with interpretation and wrote the first draft. PM, APK, ADV and TP were involved with drafting, revising and final approval. All authors read and approved the final manuscript.

#### Competing interests

The authors declare that they have no competing interests.

#### Consent for publication

Not applicable

#### Ethics approval and consent to participate

The study was conducted according to the Helsinki principles [49]. The Senate Higher Degrees committee, Research Committees of the University of the Western Cape (UWC), South Africa and the Population Health Research Institute (PHRI) in Canada approved this study (Registration #13/6/18).

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Received: 15 September 2016 Accepted: 18 November 2016
Published online: 29 December 2016

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# CHAPTER 4

**Association between perceived built environmental attributes and physical activity among adults in South Africa**

Malambo et al. BMC Public Health (2017) 17:213
DOI 10.1186/s12889-017-4128-8

BMC Public Health

RESEARCH ARTICLE

Open Access

# Association between perceived built environmental attributes and physical activity among adults in South Africa

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**Abstract**

**Background:** To investigate the association between perceived environmental attributes and leisure-time and transport-related physical activity.

**Methods:** This was a cross-sectional survey involving 671 South Africans aged ≥35 years from urban and rural settings. International Physical Activity Questionnaire and Neighbourhood Walkability Scale were used to collect data. Multivariable logistic regressions were used to investigate the associations.

**Results:** Significant urban vs. rural differences were apparent in the distribution of most attributes of neighborhood environment. After adjusting for gender, age, setting and relevant interaction terms, proximity to local stores was significantly associated with leisure-time physical activity (OR: 4.26; 95% CI, 1.00–18.08); while proximity to transit stops (2.44; 1.48–4.02), pleasant scenery (1.93; 1.07–3.46), sidewalks (2.36; 1.25–4.44), shade from trees (2.14; 1.19–3.85), traffic (2.17; 91.21–3.91) and well-lit streets (2.01; 1.04–3.89) were significantly associated with walking for leisure. Four-way intersections (4.54; 1.54–13.43), pleasant scenery (3.84; 1.35–10.99), traffic (0.28; 0.09–0.89), sidewalks (3.75; 1.06-13.27) and crosswalks were associated with transport related physical activity. Proximity to transit stops (2.12; 1.17–3.84) and well maintained sidewalks (2.69; 2.20–10.02) were significantly associated with total physical activity. Significant interactions by setting were apparent in some of the associations.

**Conclusion:** Some, but not all attributes of a neighborhood environment were significantly associated in expected directions with the three physical activity domains in this mixed urban and rural population. This study highlights the need for policy strategies aimed at improving or maintaining these perceived environmental attributes to promote physical activity.

**Keywords:** Physical activity, Built environment, Transport, Leisure, Walking, South Africa

## Background

Regular physical activity (PA) is reported to be essential for the overall health and is associated with reduction in morbidity and mortality [1]. It is estimated that lack of physical activity accounts for between 3% and 4% of deaths among South Africans men and women respectively [2]. Consequently, 3.3% of all deaths in South Africa in 2000 were attributed to physical inactivity [3]. Moreover, 48% of South African men and 63% of African women were reported as being physically 'inactive' [4].

Walking for transportation can assist people in meeting recommended levels of physical activity [1]. Accordingly, residents living in highly walkable neighborhoods are more likely to walk for leisure than those living in low-walkable neighborhoods [5]. These findings are supported by evidence from others studies that showed aesthetic environment, convenience of facilities for walking, accessibility, and perception about traffic and busy roads to be associated with walking [6].

There is a growing body of international data showing that perceived built environments are associated with physical activity [7, 8] at a population level. Perceived built environment features such as proximity to destinations, sidewalks, the presence of physically active people

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in the neighborhood, higher residential density, neighborhood safety [7] and aesthetic quality [9] have been associated with moderate to vigorous physical activity and walking. Similarly, access to services, streets connectivity, pedestrian infrastructures, heavy traffic and a mix of utilitarian and recreational destinations have been linked to active travel, recreational physical activity [8] and leisure-time physical activity and leisure-time walking [9].

The design of built environment attributes that shapes and promotes active living is vital in modern society as this helps town planners and policy makers to make decisions that could potentially improve physical activity at the neighborhood level [10]. However, there remains a gap in the literature concerning the association between perceived built environment attributes and physical activity in an African context. For instance, with a few exceptions [11], most studies in this field originate from high income countries [12]. Therefore, the aim of this study was to investigate the association between perceived environmental attributes and leisure-time and transport-related physical activity in urban and rural communities in South Africa.

## Methods

### Study design

This was a cross-sectional analysis of the baseline data of the South African arm of the Prospective Urban and Rural Epidemiology (PURE) Study collected in 2009.

### Study population and setting

The study cohort included 2064 black South African men and women, aged 35–70 years, living in rural and urban sites, and was established in 2009. Communities selection purposefully favoured communities where a follow up of each respective cohort (urban vs rural) was feasible [13]. For the urban community (Langa in Cape Town), households were grouped into three development areas recognized administratively by the City of Cape Town Municipality. A street map obtained from the City of Cape Town was used to randomly select streets in each of these 3 areas. Once a street was selected, a systematic sampling of every second house was used to select potentially eligible participants for inclusion in the study. In the rural community (Mount Frere), the absence of delineated streets precluded following the same sampling approach used for the urban township. A cluster sample of houses in the community was therefore selected according to the division of areas determined by the clan heads. The inclusion criteria for both urban and rural were as follows: (1) households with a minimum of one member who was aged 35–70 years, (2) houses situated within an identified neighborhood and (3) houses without occupants with a disability that precluded them from walking. The sampling yielded 437 households in the urban community (1061 individuals) and 329 households in the rural community (1003 individuals). All households with eligible individuals were approached for recruitment, by trained field workers. For this study, all members in each household who met the criteria were used for analysis.

### Data collection

The PURE study used standardized, interviewer-administered questionnaires previously tested for anthropometric and biochemical measurements [13]. The study used the long version of the International Physical Activity Questionnaire (IPAQ) [14] and the Neighborhood Environment Walkability Scale (NEWS) questionnaire [15].

### Covariates

Socio-demographic information on age, sex, marital status, education level, and occupation were elicited from participants using a self-administered questionnaire. Participant's age was grouped into 3 categories: 35– 44, 45–54, and 55 years or older. Marital status was classified as single, married, or divorced. Education level was classified as primary school education, secondary school education and tertiary school education. In this study, the occupation status was categorized as skilled (technicians, machine operators, clerks, skilled agriculture and fishery workers) and less skilled (homemaker, service, shop and market workers).

### Self-reported physical activity

The long version of the IPAQ was used to collect data on self-reported physical activity [16].

The IPAQ long form questionnaire assesses physical activity across a comprehensive set of domains including leisure time, domestic and gardening (yard), work-related, and transport-related physical activities, over the last 7 days. The IPAQ questionnaire was used to measure the frequency (days) and duration (in minutes) of vigorous-intensity PA, moderate-intensity PA, and walking-level PA separately. The total number of minutes per week in each PA category was computed (http://www.ipaq.ki.se). In the present study, four outcome variables were calculated: (1) leisure-time physical activity, (2) transport-related physical activity, (3) walking for leisure and (4) total physical activity. The four outcome variables were dichotomized into <150 min and ≥150 min according to WHO PA recommendations [17]. A 12-country, 14 - site study showed that the long IPAQ has excellent one-week test-retest reliability (pooled $r = 0.81$) and acceptable validity (pooled $r = 0.33$) when compared with accelerometer-measured physical activity [18].

#### Self-perceived built environment

Participants completed interviewer-administered NEWS questionnaires [19], which assess the perceived built environment on the following selected variables: land use mix–access (4 items), walking/cycling infrastructure (3 items), aesthetics (3 items), traffic (3 items) and crime (3 items). Participants were instructed to consider neighborhood as the area within a 15–20 min walk from their home. These items used 4-point Likert scale-type of responses ranging from strongly disagree (1) to strongly agree (4). For the purpose of statistical analysis, a dichotomous variable was constructed. Responses to items were collapsed into categories: "disagree" (strongly disagree and somewhat disagree) and "agree" (somewhat agree and strongly agree). The NEWS questionnaire has been shown to be reliable and valid in reflecting neighbourhood walkability and the perceived neighbourhood environment, across a broad range of countries and settings [19].

#### *Statistical analysis*

The starting sample comprised 1016 participants of whom 345 were excluded for unacceptable levels of missing data [20]. Therefore, the final analytic sample comprised 671 participants. We used SPSS® version 22 for Windows (IBM Corp: Armonk New York) for all data analyses. Descriptive statistics were computed to measure frequencies for all categorical variables. In order to test for the association between perceived built environment and physical activity, univariable and multivariable models were constructed. In unadjusted logistic regression models, we tested the association between each perceived built environment item and the 4 physical activity outcomes. Potential confounders to be adjusted for in multivariable models, were first tested for their association with each of the outcome variables in univariable logistic regressions. These included age, sex, marital status, education and occupation. None of these variables were consistently associated with the 4 outcomes of interest (data not shown). Accordingly multivariable models were adjusted only for gender and age, under the assumption that confounding factor if any (both measured and unmeasured) would tend to be associated with either age or sex. In all regression models, all those who did not meet the 150 min per week recommended guidelines were used as reference category. In univariable models, the interactions between setting (urban vs. rural) and perceived built environment variables were tested by including in the same model the main effect of setting and built environment variable of interest, as well as their interaction term. Because of the many significant interactions, the interaction term of setting with each of the built environment variable was included in relevant multivariable models using the total sample. Furthermore, we have also presented the regression models stratified by setting. Statistical significance was set at $p < 0.05$.

### Results

Table 1 shows the descriptive characteristics of the sample. The sample included more women than men (76% vs. 24%) with no significance difference between urban

**Table 1** Descriptive characteristic of individuals by location

| Variables (N (%)) | Urban = 290 | Rural = 381 | p-value | All = 671 |
|---|---|---|---|---|
| Covariates | | | | |
| Sex | | | 0.915 | |
| Males | 69 (23.8) | 92 (24.1) | | 161 (24.0) |
| Females | 221 (76.2) | 289 (79.9) | | 510 (76.0) |
| Age | | | 0.303 | |
| 35-44 | 87 (30.0) | 134 (35.2) | | 221 (32.9) |
| 45-54 | 100 (34.5) | 129 (33.9) | | 229 (34.1) |
| 55 + | 103 (35.5) | 118 (31.0) | | 221 (32.9) |
| Marital status | | | **0.019** | |
| Single | 132 (45.5) | 133 (34.9) | | 265 (39.5) |
| Married | 106 (36.6) | 171 (44.9) | | 277 (41.3) |
| Divorce | 52 (17.9) | 77 (20.2) | | 129 (19.2) |
| Education status | | | 0.165 | |
| Primary | 86 (29.7) | 190 (49.9) | | 276 (41.1) |
| Secondary | 186 (64.1) | 179 (47.0) | | 365 (54.4) |
| Tertiary | 18 (6.2) | 12 (3.1) | | 30 (4.5) |
| Occupation | | | 0.558 | |
| Less skilled | 241 (83.1) | 323 (84.8) | | 564 (84.1) |
| Skilled | 49 (16.9) | 58 (15.2) | | 107 (15.9) |
| Ethnicity | | | 0.130 | |
| Black African | 285 (98.3) | 379 (99.5) | | 664 (99.0) |
| Colored | 5 (1.7) | 2 (0.5) | | 7 (1.0) |
| Physical activity outcomes | | | | |
| Leisure-time physical activity[a] | | | 0.125 | |
| < 150 min/week | 181 (85.4) | 194 (90.2) | | 375 (87.8) |
| ≥ 150 min/week | 31 (14.6) | 21 (9.8) | | 52 (12.2) |
| Walking for leisure[a] | | | 0.095 | |
| < 150 min/week | 153 (53.3) | 226 (59.8) | | 379 (57.0) |
| ≥ 150 min/week | 134 (46.7) | 152 (40.2) | | 286 (43.0) |
| Transport-related physical activity[a] | | | **0.018** | |
| < 150 min/week | 199 (84.7) | 255 (91.4) | | 454 (88.3) |
| ≥ 150 min/week | 36 (15.3) | 24 (8.6) | | 60 (11.7) |
| Total physical activity | | | **<0.001** | |
| < 150 min/week | 63 (21.7) | 146 (38.3) | | 209 (31.1) |
| ≥ 150 min/week | 227 (78.3) | 235 (61.7) | | 462 (68.9) |

[a]sub sample less than 671 due to missing variables
Bold is significant p value

and rural areas ($p = 0.915$). Over 34% of the subjects were aged 45–54 years, similarly in urban and rural areas ($p = 0.303$). In all, 41.3% of the participants were married with significant urban vs. rural difference (36.6% vs. 44.9%, $p = 0.019$). Over 54.4% were educated to a secondary school level and only 15.9% had skilled jobs and majority were black Africans (99.0%) from rural areas (56.8%), with no rural vs. urban differences in these characteristics (all p ≥0.130; Table 1).

Only 12.2% of respondents met recommended physical activity guidelines (≥150 min/week) in the leisure-time domain. There was no difference in the prevalence of those persons accumulating at least 150 min/week of moderate-to-vigorous activity in leisure time, between urban and rural settings (14.6% vs 9.8%, $p = 0.125$). Overall, 57.0% of respondents did not accumulate at least 150 min per week of walking for leisure. This pattern was observed in both urban and rural settings (53.3% vs 57.8%), $p = 0.095$). For transport-related physical activity, the proportion of respondents achieving at least 150 min per week was 11.7% in the overall sample, and 15.3% in urban and 8.6% in rural areas, respectively ($p = 0.018$). Altogether, 68.9% of the respondents met the global recommendations of at least 150 min of moderate-to-vigorous physical activity per week (combining all domains). In fact, total moderate-to-vigorous activity prevalence was higher in the urban community (compared to the rural sample (78.3% vs.61.7%, $p < 0.001$; Table 1).

Table 2 illustrates the attributes of built environment overall and by location. The majority of respondents (68%) said they were able to do most of their shopping at a local store within walking distance from their homes. Destinations within neighborhoods were widely reported with more than 73% agreeing that there were many places to go within easy walking distance and 75% reporting that it was easy to walk to a transit stop from their residences. Approximately half the respondents (51%) felt that the distance between intersections was short, 54% agreed that there were many four-way intersections and 68% reported many alternative routes in their neighborhood. Despite over 54% agreeing that there were sidewalks on most streets, 52% reported sidewalks were not well maintained and not separated by grass from the streets. Almost half of the respondents indicated that there were no trees and a lack of pleasant scenery (interesting things) to see while walking and neighborhood was full of litter. Although 53% of the respondents reported a high volume of traffic along their streets, over 64% reported low volumes of traffic along nearby streets. Approximately half (51%) indicated that crosswalks did not help in crossing busy streets. The majority (57.1%) of the respondents reported that streets in their neighborhood were poorly lit at night, with 52% and 74% during the day/night respectively reporting that it was difficult to walk due to high crime rates (Table 2). In general, all built environment attributes were significantly different in urban and rural areas (all $p < 0.001$; Table 2).

The univariable regression analyses in the overall sample are summarized in Table 3, showing some significant associations between built environment attributes and physical activity, but also a number of significant interactions, by setting, for those associations. In unadjusted regression analyses stratified by setting (Table 4), among urban dwellers who agreed that there were many four-way intersections, sidewalks were well maintained and separated from streets by grass and clean neighborhood were positively associated with leisure-time physical activity (all $p < 0.05$), Table 4. In addition, transit stop, four-way intersections, all infrastructure variables, pleasant scenery and well-lit streets at night were positively associated with walking for leisure (all $p < 0.05$). This pattern was almost similar for total physical activity (Table 4). Meanwhile among rural counterparts, shade from trees and pleasant scenery were positively associated with leisure-time physical activity (both $p < 0.05$). In addition, alternative routes and crosswalks were both associated with walking for leisure ($p < 0.05$). Those who agreed that streets were well maintained and separated from street by grass were more likely to participate in transport related physical activity (both $p < 0.05$), Table 4. Similarly, alternative routes in rural area were positively associated with total physical activity. Conversely, among urban respondents, high traffic volume and crime rate at night were inversely associated with walking for leisure (both $p < 0.05$. Meanwhile in the rural area, high crime rate at night and traffic volume were negatively associated with leisure-time physical activity, walking for leisure and total physical activity (all $p < 0.05$; Table 4), respectively.

The gender, age and site (and relevant interact terms in the overall sample) adjusted models are shown in Table 5 and 6. In these models applied to overall sample, significant associations were apparent between proximity to local stores and leisure time physical activity (4.26; 1.00-18.08), proximity to transit stop and walking for leisure (2.44; 1.48-4.02), proximity to transit stop and total physical activity (2.12; 1.17-3.84), availability of four-way intersections and transport related physical activity (4.54; 1.54-13.43), interesting things and walking for leisure (1.93; 1.07-3.46), interesting things and transport related physical activity (3.84; 1.35-10.93), and too much traffic along the street and leisure time related physical activity (0.28; 0.09-0.89). These associations were found in both urban and rural areas, although not always of the same magnitude, and not always statistically significant in each setting, separately (Table 6).

In the overall sample significant associations were also found between availability of sidewalks and walking for

**Table 2** Descriptive characteristics of built environment attributes by location

| Variables (N (%)) | Urban = 290 | Rural = 381 | p-value | All = 671 |
|---|---|---|---|---|
| Environmental attributes | | | | |
| Land use mix-access | | | | |
| I can do most of my shopping at local stores | | | **<0.001** | |
| Agree | 243 (83.8) | 218 (57.2) | | 461 (68.7) |
| Disagree | 47 (16.2) | 163 (42.8) | | 210 (31.3) |
| Stores are within easy walking distance of my home | | | **<0.001** | |
| Agree | 243 (83.8) | 218 (57.2) | | 461 (68.7) |
| Disagree | 47 (16.2) | 163 (42.8) | | 210 (31.3) |
| There are many places to go within easy walking distance of my home | | | **<0.001** | |
| Agree | 258 (89.0) | 237 (62.2) | | 495 (73.8) |
| Disagree | 32 (11.0) | 144 (37.8) | | 176 (26.2) |
| It is easy to walk to a transit stop (bus, train) from my home | | | **<0.001** | |
| Agree | 258 (89.0) | 249 (65.4) | | 507 (75.6) |
| Disagree | 32 (11.0) | 132 (34.6) | | 164 (24.4) |
| Street connectivity | | | | |
| The distance between intersections in my neighborhood is usually short | | | **<0.001** | |
| Agree | 238 (82.1) | 87 (22.8) | | 325 (48.4) |
| Disagree | 52 (17.9) | 294 (77.2) | | 346 (51.6) |
| There are many four-way intersections in my neighborhood | | | **<0.001** | |
| Agree | 240 (82.8) | 125 (32.8) | | 365 (54.4) |
| Disagree | 50 (17.2) | 256 (67.2) | | 306 (45.6) |
| There are many alternative routes for getting from place to place in my neighborhood | | | **<0.001** | |
| Agree | 248 (85.5) | 208 (54.6) | | 456 (68.0) |
| Disagree | 42 (14.5) | 173 (45.4) | | 215 (32.0) |
| Places for walking and cycling | | | | |
| There are sidewalks on most of the streets in my neighborhood | | | **<0.001** | |
| Agree | 246 (84.8) | 118 (31.0) | | 364 (54.2) |
| Disagree | 44 (15.2) | 263 (69.0) | | 307 (45.8) |
| The sidewalks in my neighborhood are well maintained | | | **<0.001** | |
| Agree | 224 (77.2) | 97 (25.5) | | 321 (47.8) |
| Disagree | 66 (22.8) | 284 (74.5) | | 350 (52.2) |
| There is a grass/dirt strip that separates the streets from the sidewalks in my neighborhood | | | **<0.001** | |
| Agree | 199 (68.6) | 122 (32.0) | | 321 (47.8) |
| Disagree | 91 (31.4) | 259 (68.0) | | 350 (52.2) |
| Neighborhood surroundings | | | | |
| Trees give shade for the sidewalks in my neighborhood | | | **<0.001** | |
| Agree | 198 (68.3) | 114 (29.9) | | 312 (46.6) |
| Disagree | 92 (31.7) | 267 (70.1) | | 359 (53.5) |
| There are many interesting things to look at while walking in my neighborhood. | | | **<0.001** | |
| Agree | 210 (72.4) | 104 (27.3) | | 314 (46.8) |
| Disagree | 80 (27.6) | 277 (72.7) | | 357 (53.2) |

**Table 2** Descriptive characteristics of built environment attributes by location *(Continued)*

| | | | | |
|---|---|---|---|---|
| My neighborhood is generally free from litter | | | **<0.001** | |
| Agree | 173 (59.7) | 107 (28.1) | | 280 (41.7) |
| Disagree | 117 (40.3) | 274 (71.9) | | 391 (58.3) |
| Safety from traffic | | | | |
| There is so much traffic along the street I live such that it makes it difficult to walk in my neighborhood | | | **<0.001** | |
| Agree | 235 (81.0) | 127 (33.3) | | 362 (53.9) |
| Disagree | 55 (19.0) | 254 (66.7) | | 309 (46.1) |
| There is so much traffic along nearby streets that it makes it difficult to walk in my neighborhood | | | **<0.001** | |
| Agree | 179 (61.7) | 61 (16.0) | | 240 (35.8) |
| Disagree | 111 (38.3) | 320 (84.0) | | 431 (64.2) |
| The crosswalks in my neighborhood help walkers feel safe crossing busy streets | | | **<0.001** | |
| Agree | 228 (78.6) | 98 (25.7) | | 326 (48.6) |
| Disagree | 62 (21.4) | 283 (74.3) | | 345 (51.4) |
| Safety from crime | | | | |
| My neighborhood streets are well lit at night | | | **<0.001** | |
| Agree | 234 (80.7) | 54 (14.2) | | 288 (42.9) |
| Disagree | 56 (19.3) | 327 (85.8) | | 383 (57.1) |
| The crime rate in my neighborhood makes it unsafe to go on walks during the day | | | **<0.001** | |
| Agree | 22 (76.2) | 133 (34.9) | | 354 (52.8) |
| Disagree | 69 (23.8) | 248 (65.1) | | 317 (47.2) |
| The crime rate in my neighborhood makes it unsafe to go on walks at night | | | **<0.001** | |
| Agree | 243 (83.8) | 257 (67.5) | | 500 (74.5) |
| Disagree | 47 (16.2) | 124 (32.5) | | 171 (25.5) |

Bold is significant *p* value

leisure (2.36; 1.25-4.44), availability of sidewalks and transport related physical activity (3.75; 1.06-13.27), availability of maintained sidewalks and total physical activity (4.69; 2.20-10.02), shaded (trees) sidewalks and walking for leisure (2.14; 1.19-3.85), too much traffic along the street and walking for leisure (2.17; 91.21-3.91), crosswalks and transport related physical activity (4.11; 1.47-11.50), and well lighted streets at night and walking for leisure (2.01; 1.04-3.89). When rural and urban settings were considered separately, these associations were not always in the same direction, not always significant, nor did that always result in significant interactions by setting (Table 6).

Finally, some significant associations were found in setting specific analyses, but not in the overall sample. These included the associations of leisure time physical activity with transit stops and crime rates in rural setting, the association of walking for leisure with availability of well-maintained sidewalks in urban setting, the associations of total physical activity with availability of four-way intersections, neighborhoods free from litter and well-lit streets at night in urban settings, and shaded sidewalks in rural setting (Table 6).

## Discussion

A proportion of subjects reached 150-min per week threshold in total physical activity outcomes. After adjusting for gender, age and site (including interaction terms), attributes of the built environment including proximity to local stores, transit stops, four-way intersections, the availability of sidewalks and crosswalks, shade from trees and pleasant scenery, as well as a high volume of traffic, well-lit streets at night and concerns of personal safety during the day were associated with meeting physical activity guidelines of accumulating at least 150 min of moderate-to-vigorous activity per week, among the urban and rural South Africans surveyed.

This study supports the growing evidence that proximity and ease of access to destinations and services such as local stores and transit stops from residences are linked to more active living including [21] leisure-time

**Table 3** Odd ratios and 95% confidence intervals from crude logistic regressions between environmental factors and physical activity in the overall sample

| Variables | LTPA | WL | TRPA | TPA | Setting * built environment factors | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | Setting*LTPA p | Setting *WL p | Setting *TRPA p | Setting *TPA p |
| Built environmental factors (agree vs disagree) | | | | | | | | |
| Land use mix-access | | | | | | | | |
| I can do most of my shopping at local stores | 1.70 (0.82-3.51) | 0.86 (0.61-1.22) | 0.85 (0.45-1.50) | 1.05 (0.74-1.49) | 0.053 | 0.807 | 0.755 | 0.942 |
| Stores are within easy walking distance of my home | 1.70 (0.82-3.51) | 0.86 (0.61-1.22) | 0.85 (0.45-1.50) | 1.05 (0.74-1.49) | 0.053 | 0.807 | 0.755 | 0.942 |
| There are many places to go within easy walking distance of my home | 1.21 (0.58-2.52) | 0.97 (0.68-1.40) | 0.96 (0.52-1.76) | 1.12 (0.78-1.62) | 0.536 | 0.736 | 0.891 | 0.149 |
| It is easy to walk to a transit stop (bus, train) from my home | **2.20*** (1.01-8.30) | **1.71**** (1.17-2.50) | **2.36*** (1.09-5.12) | **2.67***** (1.57-3.26) | 0.478 | 0.052 | 0.850 | 0.781 |
| Street connectivity | | | | | | | | |
| The distance between intersections in my neighborhood is usually short | 1.33 (0.73-2.40) | 1.23 (0.90-1.69) | **2.05*** (1.17-3.59) | **1.72**** (1.23-2.4) | 0.056 | 0.824 | 0.935 | 0.742 |
| There are many four-way intersections in my neighborhood | 1.10 (0.60-1.10) | 0.75 (0.54-1.03) | 0.84 (0.49-1.44) | 1.31 (0.95-1.82) | **0.018** | 0.185 | 0.421 | **0.007** |
| There are many alternative routes in my neighborhood | 1.91 (0.90-4.05) | 0.75 (0.54-1.06) | 1.11(0.61-2.01) | 1.07 (0.75-1.51) | 0.979 | 0.066 | 0.730 | **0.015** |
| Infrastructure for walking and cycling | | | | | | | | |
| There are sidewalks on most of the streets in my neighborhood | 1.31 (0.72-2.30) | **1.54**** (1.12-2.12) | 1.11 (0.65-1.92) | 1.10 (0.79-1.53) | 0.063 | **0.002** | 0.847 | **0.015** |
| The sidewalks in my neighborhood are well maintained | 1.31 (0.72-2.38) | 0.76 (0.55-1.04) | 0.98 (0.57-1.68) | 0.78 (0.56-1.08) | **0.004** | **<0.001** | **0.036** | **0.034** |
| There is a grass that separates the streets from the sidewalks | 1.56 (0.86-2.82) | **1.40*** (1.01-1.92) | 0.82 (0.48-1.41) | 1.09 (0.78-1.51) | **0.016** | **0.001** | 0.134 | **<0.001** |
| Aesthetics | | | | | | | | |
| Trees give shade for the sidewalks in my neighborhood. | 1.39 (0.77-2.49) | 0.96 (0.69-1.31) | 1.43 (0.83-2.46) | 1.33 (0.96-1.85) | **0.026** | 0.614 | 0.551 | 0.963 |
| There are many interesting things to look at while walking | 0.89 (0.50-1.60) | 0.83 (0.61-1.15) | **1.90*** (1.09-3.32) | **1.43*** (1.03-2.00) | **0.020** | 0.214 | 0.412 | 0.824 |
| My neighborhood is generally free from litter. | 0.94 (0.52-1.67) | **1.49*** (1.08-2.06) | 1.61 (0.94-2.76) | **1.38** (0.99-1.94) | **0.034** | 0.963 | 0.105 | 0.098 |
| Safety from traffic | | | | | | | | |
| Too much traffic along the street I live in makes it difficult walk | 0.66 (0.37-1.78) | **0.48***** (0.35-0.66) | 1.11 (0.64-1.92) | 0.98 (0.71-1.36) | 0.938 | 0.788 | 0.919 | 0.148 |
| Too much traffic along nearby streets makes it difficult walk | 0.77 (0.42-1.40) | 0.74 (0.53-1.04) | 1.10 (0.64-1.91) | 0.81 (0.58-1.45) | 0.180 | 0.726 | 0.762 | 0.497 |
| The crosswalks help walkers feel safe crossing busy streets | 1.14 (0.63-2.05) | 0.81(0.59-1.11) | 0.86 (0.50-1.47) | 1.31 (0.94-1.81) | 0.670 | 0.668 | 0.857 | 0.640 |

**Table 3** Odd ratios and 95% confidence intervals from crude logistic regressions between environmental factors and physical activity in the overall sample *(Continued)*

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Safety from crime | | | | | | | | |
| My neighborhood streets are well lit at night | 1.37 (0.76-2.46) | 1.75 (0.91-3.36) | **1.78*** (1.04-3.07) | **2.07***** (1.46-2.92) | 0.925 | **0.015** | 0.299 | 0.165 |
| The crime rate makes it unsafe to go on walks during the day | 0.75 (0.42-1.35) | 1.30 (0.68-2.49) | 0.75 (0.44-1.31) | 0.75 (0.54-1.04) | **0.015** | 0.391 | 0.248 | 0.596 |
| The crime rate makes it unsafe to go on walks at night | 0.78 (0.37-1.61) | **0.41*** (0.18-0.90) | 0.60 (0.29-1.22) | 0.89 (0.61-1.30) | 0.967 | 0.308 | 0.678 | 0.086 |

*LTPA* Leisure time physical activity, *WL* Walking for leisure, *TRPA* Transport related physical activity, *TPA* Total physical activity, *P* p-value; $^{*}p < 0.05$; $^{**}p < 0.01$; $^{***}p < 0.001$
Bold is significant *p* value

**Table 4** Odd ratios and 95% confidence intervals from crude logistic regression between environmental factors and physical activity (ref <150mins/week) in urban and rural participants

| Variables | Urban | | | | Rural | | | |
|---|---|---|---|---|---|---|---|---|
| | LTPA | WL | TRPA | TPA | LTPA | WL | TRPA | TPA |
| Environmental factors (agree vs disagree) | | | | | | | | |
| Land use mix-access | | | | | | | | |
| I can do most of my shopping at local stores | **7.19** (0.95-54.55) | 1.37 (0.73-2.56) | 1.62 (0.70-3.75 | 1.43 (0.63-3.23) | 0.80 (0.32-2.00) | 1.24 (0.82-1.88) | 1.34 (0.58-3.10) | 1.34 (0.88-2.05) |
| Stores are within easy walking distance of my home | **7.19** (0.95-54.55) | 1.37 (0.73-2.56) | 1.62 (0.70-3.75 | 1.43 (0.63-3.23) | 0.80 (0.32-2.00) | 1.24 (0.82-1.88) | 1.34 (0.58-3.10) | 1.34 (0.88-2.05 |
| There are many places to go within easy walking distance of my home | 1.50 (0.33-6.86) | 1.34 (0.64-2.79) | 1.30 (0.46-3.68) | 0.68 (0.30-1.55) | 0.86 (0.34-2.17) | 1.16 (0.76-1.76) | 1.43 (0.61-3.31) | 1.34 (0.87-2.07) |
| It is easy to walk to a transit stop (bus, train) from my home | 1.70 (0.38-7.70) | **2.03****(1.19-2.81) | 2.22 (0.50-9.87) | **1.83**** (1.19-2.81) | 3.66 (0.83-16.27) | 0.86 (0.41-1.80) | 1.87 (0.72-4.88) | **2.08** (0.94-4.54) |
| Street connectivity | | | | | | | | |
| The distance between intersections in my neighborhood is usually short | 2.88 (0.65-12.73) | 1.03 (0.56-1.88) | 1.71 (0.57-5.14) | 1.25 (0.62-2.53) | 0.43 (0.12-1.53) | 1.12 (0.69-1.83) | 1.61 (0.63-4.08) | 1.09 (0.66-1.79) |
| There are many four-way intersections in my neighborhood | **3.70*** (1.05-12.99) | **2.17****(1.37-3.45) | 1.61 (0.67-3.87) | **1.57*** (1.02-2.43) | 0.21 (0.03-1.59) | 1.29 (0.70-2.38) | 2.87 (0.95-8.65) | **0.52** (0.26-1.02) |
| There are many alternative routes in my neighborhood | 1.70 (0.38-7.70) | 0.92 (0.47-1.81) | 1.03 (0.37-2.87) | 0.56 (0.27-1.16) | 1.66 (0.64-4.30) | **1.94****(1.28-2.94) | 1.30 (0.56-3.00) | **1.59*** (1.05-2.43) |
| Infrastructure for walking and cycling | | | | | | | | |
| There are sidewalks on most of the streets in my neighborhood | 4.15 (0.54-31.98) | **3.55*****(2.15-5.88) | 1.68 (0.70-4.03) | **2.02**** (1.30-3.15) | 0.42 (0.12-1.49) | 0.99 (0.52-1.90) | 1.90 (0.73-4.96) | 0.70 (0.34-1.45) |
| The sidewalks in my neighborhood are well maintained | **10.52*** (1.40-79.31) | **3.41*****(1.98-5.88) | 0.83 (0.36-1.94) | **3.31*****(2.06-5.34) | 0.26 (0.06-1.15) | 0.76 (0.44-1.34) | **5.12*** (1.18-22.30) | 1.33(0.66-2.67) |
| There is a grass that separates the streets from the sidewalks | **2.78*** (1.02-7.58) | **2.63*****(1.64-4.23) | 1.11 (0.52-2.35) | **2.51*****(2.06-5.34) | 0.44 (0.14-1.35) | 0.82 (0.50-1.36) | **3.07*** (1.02-9.25) | 0.62(0.35-1.11) |
| Aesthetics | | | | | | | | |
| Trees give shade for the sidewalks in my neighborhood | 0.70 (0.30-1.66) | 1.22 (0.74-2.00) | 1.35 (0.62-2.96) | 1.00(0.55-1.82) | **3.95*** (1.13-13.86) | 1.02 (0.65-1.60) | 0.93 (0.37-2.34) | 0.98(0.63-1.54) |
| There are many interesting things to look at while walking | 0.65 (0.25-1.67) | **1.75*** (1.09-2.83) | 2.06 (0.81-5.20) | 1.04(0.56-1.95) | **5.24*** (1.19-23.18) | 1.12 (0.67-1.88) | 1.20 (0.49-2.92) | 0.95(0.60-1.52) |
| My neighborhood is generally free from litter. | **2.33** (0.99-5.48) | 1.32 (0.82-2.12) | 2.04 (0.95-4.36) | 0.75(0.42-1.33) | 0.50 (0.16-1.55) | 1.34 (0.85-2.11) | 0.71 (0.26-1.97) | 1.40(0.88-2.24) |
| Safety from traffic | | | | | | | | |
| Too much traffic along the street I live in makes it difficult walk | **0.39*** (0.16-0.95) | **0.39****(0.21-0.71) | 0.83 (0.35-1.96) | 1.01(0.49-2.05) | 0.42 (0.14-1.29) | **0.35*****(0.22-0.56) | 0.78 (0.32-1.88) | **054****(0.35-.84) |
| Too much traffic along nearby streets makes it difficult walk | 0.76 (0.35-1.65) | 0.66 (0.41-1.06) | 0.74 (0.36-1.52) | 0.91(0.51-1.62) | 0.17 (0.22-1.31) | 0.57 (0.32-1.04) | 0.91 (0.30-2.79) | 0.69(0.40-1.20) |

**Table 4** Odd ratios and 95% confidence intervals from crude logistic regression between environmental factors and physical activity (ref <150mins/week) in urban and rural participants *(Continued)*

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| The crosswalks help walkers feel safe crossing busy streets | 1.26 (0.47-3.34) | 1.40 (0.80-2.46) | 1.86 (0.84-4.12 | 1.06(0.53-2.11) | 1.12 (0.41-3.03) | **1.65*** (1.01-2.68) | 2.12 (0.70-6.42) | 1.29(0.81-2.06) |
| Safety from crime | | | | | | | | |
| My neighborhood streets are well lit at night | 1.01 (0.36-2.84) | **2.07*** (1.16-3.70) | 0.95 (0.35-2.33) | **1.99***(1.04-3.80) | 0.94 (0.30-2.95) | 0.74 (0.41-1.34) | 1.97 (0.69-5.68) | 1.07(0.59-1.93) |
| The crime rate makes it unsafe to go on walks during the day | 1.34 (0.52-3.47) | 0.67 (0.39-1.15) | 0.72 (0.32-1.60) | 1.12(0.59-2.13) | **0.19****(0.05-0.66) | 0.90 (0.59-1.39) | **1.43 (0.61-3.35)** | 0.91(0.59-1.40) |
| The crime rate makes it unsafe to go on walks at night | 0.85 (0.27-2.61) | **0.48*** (0.25-0.92) | 0.78 (0.28-2.16) | 1.29(0.63-2.66) | 0.87 (0.32-2.36) | 0.72 (0.47-1.12) | 0.56 (0.21-1.60) | **0.61***(0.39-.96) |

*LTPA* Leisure time physical activity, *WL* Walking for leisure, *TRPA* Transport related physical activity, *TPA* Total physical activity; *$p < 0.05$; **$p < 0.01$; ***$p < 0.001$
Bold is significant $p$ value

**Table 5** Odd ratios and 95% confidence intervals from adjusted logistic regression between environmental factors and physical activity in urban and rural participants in the overall sample

| | Physical activity outcomes | | | |
|---|---|---|---|---|
| Variables[a] | LTPA | WL | TRPA | TPA |
| Environmental factors (agree vs disagree) | | | | |
| Land use mix-access | | | | |
| I can do most of my shopping at local stores | **4.26*** (1.00-18.06) | 1.38 (0.76-2.51) | 0.87 (0.35-2.16) | 0.73(0.39-1.38) |
| There are many places to go within easy walking distance of my home | 0.46 (0.14-1.84) | 1.01 (0.54-1.90) | 0.81 (0.27-2.46) | 0.93 (0.46-1.87) |
| It is easy to walk to a transit stop (bus, train) from my home | 3.72 (0.85-16.28) | **2.44***** (1.48-4.02) | 2.58 (0.77-8.66) | **2.12***(1.17-3.84) |
| Street connectivity | | | | |
| The distance between intersections in my neighborhood is usually short | 1.01 (0.27-3.80) | 1.45 (0.75-2.80) | **3.53** (0.96-12.91) | 0.68 (0.34-1.38) |
| There are many four-way intersections in my neighborhood | 0.85 (0.22-3.21) | 0.59 (0.31-1.14) | **4.54**** (1.56-13.43) | 1.85 (0.93-3.65) |
| There are many alternative routes in my neighborhood | 2.37 (0.63-8.92) | 0.82 (0.48-1.40) | 1.35 (0.49-3.74) | 0.95 (0.51-1.76) |
| Infrastructure for walking and cycling | | | | |
| There are sidewalks on most of the streets in my neighborhood | 0.71 (0.17-2.89) | **2.36**** (1.25-4.44) | **3.75*** (1.06-13.27) | 1.13 (0.56-2.27) |
| The sidewalks in my neighborhood are well maintained | 0.52 (0.15-1.81) | 1.12 (0.55-2.27) | 0.58 (0.19-1.73) | **4.69***** (2.20-10.02) |
| There is a grass that separates the streets from the sidewalks | 1.85 (0.71-4.85) | 0.83 (0.45-1.54) | 0.96 (0.42-2.23) | 1.30 (0.74-2.28) |
| Aesthetics | | | | |
| Trees give shade for the sidewalks in my neighborhood | 1.07 (0.37-3.05) | **2.14*** (1.19-3.85) | 1.02 (0.38-2.78) | 1.11 (0.59-2.09) |
| There are many interesting things to look at while walking | 0.72 (0.24-2.22) | **1.93*** (1.07-3.46) | **3.84*** (1.35-10.93) | 0.92 (0.49-1.73) |
| My neighborhood is generally free from litter | 1.50 (0.65-3.45) | 1.34 (0.85-2.11) | 1.56 (0.75-3.23) | 1.04 (0.64-1.68) |
| Safety from traffic | | | | |
| Too much traffic along the street I live in makes it difficult walk | **0.28*** (0.09-0.89) | **2.17*** (1.21-3.91) | 0.76 (0.28-2.06) | 0.93 (0.50-1.74) |
| Too much traffic along nearby streets makes it difficult walk | 1.28 (0.46-3.58) | 1.05 (0.54-2.03) | 0.89 (0.36-2.23) | 0.90 (0.49-1.66) |
| The crosswalks help walkers feel safe crossing busy streets | 0.64 (0.20-1.98) | 0.73 (0.38-1.43) | **4.11**** (1.47-11.50) | 1.08 (0.56-2.07) |
| Safety from crime | | | | |
| My neighborhood streets are well lit at night | 0.70 (0.23-2.18) | **2.01*** (1.04-3.89) | 1.52 (0.43-5.38) | 2.50 (1.24-5.04) |
| The crime rate makes it unsafe to go on walks during the day | 0.44 (0.17-1.17) | 0.87 (0.49-1.52) | 0.89 (0.34-2.36) | 1.10 (0.61-1.99) |
| The crime rate makes it unsafe to go on walks at night | 1.42 (0.46-4.41) | 0.91 (0.54-1.51) | 1.70 (0.57-5.04) | 0.83 (0.46-1.52 |

*LTPA* Leisure time physical activity, *WL* Walking for leisure, *TRPA* Transport related physical activity, *TPA* Total physical activity;[a] adjusted for age, sex, site and the interaction term of site with each of the predictors of interest; *$p < 0.05$; **$p < 0.01$; ***$p < 0.001$
Bold is significant *p* value

physical activity, walking for leisure and total physical activity. These results are aligned with the results from an 11-country, International Physical Activity and Environment Network study [22]. Similarly, a study in China found access to physical activity destinations were related to leisure-time physical activity [9]. Access to services has been associated with sufficient walking in some studies [23] but not all [24]. Although the current study did not ask the participants about ownership of cars, it is unlikely that many people owned one, and thus walking for transport is their only means of travel [25].

We found that the occurrence of short distances between intersections and 4-way intersections in the neighborhood was significantly associated with respondents achieving 150 min or more of transport-related physical activity. This mirrors outcomes in most existing studies [6], with one exception [26]. The latter study, however, was confined to the university environment and consequently their perception of street connectivity may have been different from other studies [26]. Nevertheless, similar to other studies, the possible interpretation for a positive association would be that the availability of well-connected streets provides direct routes and safety for commuters, which ultimately increases the opportunity to walk. In a South African context, and particularly in urban areas where most of the streets are tarred and well connected, it facilitates residents' use of streets for transport related physical activity.

Similar to existing studies [27], we also found that the presence of sidewalks on most streets was positively associated with walking for leisure. Likewise, better-

**Table 6** Odd ratios and 95% confidence intervals from adjusted logistic regression between environmental factors and physical activity in urban and rural participants (ref <150mins/week)

| | Urban | | | | Rural | | | |
|---|---|---|---|---|---|---|---|---|
| Variables | LTPA | WL | TRPA | TPA | LTPA | WL | TRPA | TPA |
| Environmental factors (agree vs disagree) | | | | | | | | |
| Land use mix-access | | | | | | | | |
| I can do most of my shopping at local stores | 6.76 (0.68-66.10) | 1.20 (0.35-4.07) | 0.38 (0.11-1.26) | 0.60 (0.15-2.41 | 4.18 (0.40-44.05) | 1.81 (0.64-5.18 | 0.86 (0.16-4.73) | 2.14 (0.69-6.65) |
| There are many places to go within easy walking distance of my home | 0.33 (0.03-3.46) | 0.51 (0.07-3.73) | 1.52 (0.23-9.97) | 1.75 (0.20-15.43) | 0.57 (0.08-3.98) | 0.73 (0.26-2.04) | 0.25 (0.05-1.26) | 0.57 (0.18-1.78) |
| It is easy to walk to a transit stop (bus, train) from my home | 1.21 (0.15-9.72) | **4.80*****(2.08-11.12) | 1.41 (0.18-11.14) | 4.12 (0.52-32.79) | **9.78*** (1.05-91.26) | 1.80 (0.30-10.77) | 2.12 (0.60-7.49) | **3.84**** (1.75-8.46) |
| Street connectivity | | | | | | | | |
| The distance between intersections in my neighborhood is usually short | 1.86 (0.23-14.92) | 2.21 (0.60-8.10) | **8.10*** (1.12-58.79) | 1.47 (0.23-9.25) | 2.40 (0.23-25.40) | 0.42 (0.11-1.59) | 3.61 (0.57-22.92) | 1.02 (0.32-3.27) |
| There are many four-way intersections in my neighborhood | 5.61 (0.42-9.02) | 0.88 (0.21-3.68) | **6.62***(1.42-30.82) | **16.57*** (1.78-154.49) | 0.13 (0.01-2.25) | 1.27 (0.40-4.09) | 2.68 (0.41-17.39) | 2.17 (0.65-7.29) |
| There are many alternative routes in my neighborhood | 1.02 (0.12-9.02) | 0.76 (0.16-3.57) | 1.17 (0.24-5.75) | 0.34 (0.05-2.39) | 3.39 (0.65-16.62) | 0.75 (0.30-1.86) | **3.57** (0.95-13.38) | 1.10 (0.43-2.82) |
| Infrastructure for walking and cycling | | | | | | | | |
| There are sidewalks on most of the streets in my neighborhood | 2.19 (0.16-31.09) | **3.36*** (1.07-10.51) | 0.25 (0.04-1.59) | 0.21 (0.03-1.72) | 1.26 (0.09-17.54) | 0.44 (0.09-2.21) | 1.36 (0.24-7.66) | 0.49 (0.19-1.25) |
| The sidewalks in my neighborhood are well maintained | 8.57 (0.56-30.08) | **8.06*** (1.58-41.09) | 0.33 (0.07-1.64) | **4.49** (0.98-20.62) | 0.07 (0.00-6.66) | 0.67 (0.22-2.08) | 7.49 (0.36-154.60) | 0.92 (0.22-3.77) |
| There is a grass that separates the streets from the sidewalks | 2.27 (0.63-8.21) | 1.53 (0.59-3.97) | 0.64 (0.22-1.83) | 2.16 (0.75-6.23) | 4.16 (0.14-23.44 | 1.40 (0.39-5.04) | 0.70 (0.07-7.02) | 0.37 (0.08-1.60) |
| Aesthetics | | | | | | | | |
| Trees give shade for the sidewalks in my neighborhood | 0.84 (0.20-3.61) | 0.96 (0.33-2.78) | 0.47 (0.12-1.91) | 0.96 (0.16-5.91) | 0.11 (0.01-1.49) | **2.94** (0.10-8.71) | 1.53 (0.29-7.10) | **3.05** (0.97-9.60) |
| There are many interesting things to look at while walking | 1.14 (0.24-5.51) | **3.38*** (1.25-9.15) | **12.49**** (2.04-76.43) | 0.85 (0.14-5.17) | 0.63 (0.05-8.83) | 30.74 (0.24-2.29) | 3.97 (0.81-19.50) | 0.76 (0.22-2.63) |
| My neighborhood is generally free from litter | 1.88 (0.56-6.30) | 1.15 (0.49-2.69) | 2.63 (0.88-7.87) | **4.01*** (1.23-13.03) | 0.40 (0.05-3.02) | 1.71 (0.72-4.03) | 0.29 (0.05-1.67) | 0.70 (0.28-1.75) |
| Safety from traffic | | | | | | | | |
| Too much traffic along the street I live in makes it difficult walk | **0.19*** (0.04-0.80) | 0.39 (0.12-1.29) | 0.81 (0.22-2.91) | 0.96 (0.20-4.66) | 0.19 (0.02-2.18) | 1.07 (0.37-3.09) | 1.39 (0.29-7.34) | 1.26 (0.42-3.81) |
| | 1.18 (0.31-4.41) | 0.59 (0.20-1.73) | 0.65 (0.21 (2.02) | 0.52 (0.15-1.84) | 0.44 (0.01-15.01) | 1.22 (0.31-4.73) | 0.51 (0.04-5.93) | 0.68 (0.19-2.42) |

**Table 6** Odd ratios and 95% confidence intervals from adjusted logistic regression between environmental factors and physical activity in urban and rural participants (ref <150mins/week) *(Continued)*

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Too much traffic along nearby streets makes it difficult walk | | | | | | | | |
| The crosswalks help walkers feel safe crossing busy streets | 0.65 (0.13-3.12) | 0.59 (0.19-1.85) | 2.97 (0.77-11.48) | 0.19 (0.03-1.14) | **24.41**(0.75-94.15) | 0.76 (0.22-2.60) | **14.34*** (1.23-67.56) | 0.95 (0.27-3.38) |
| Safety from crime | | | | | | | | |
| My neighborhood streets are well lit at night | 0.40 (0.08-1.99) | **10.26**** (1.92-54.80) | 0.72 (0.12-4.31) | **8.58**** (1.72-42.81) | 0.91 (0.11-7.62) | 0.66 (0.21-1.90) | 5.61 (0.64-49.36) | 2.31 (0.61-8.74) |
| The crime rate makes it unsafe to go on walks during the day | 0.82 (0.19-3.55) | 0.63 (0.21-2.49) | 0.39 (0.10-1.49) | 1.79 (0.50-6.40) | **0.04***(00.0-0.65) | 1.08 (0.41-2.85) | 2.07 (0.35-12.38) | 0.64 (0.25-1.68) |
| The crime rate makes it unsafe to go on walks at night | 0.40 (0.07-2.46) | 0.63 (0.16-2.49) | 2.08 (0.40-10.89) | 0.51 (0.10-2.59) | 2.17 (0.39-11.96) | 0.69 (0.29-1.66) | 2.53 (0.58-11.16) | 0.84 (0.34-2.04) |

*LTPA* Leisure time physical activity, *WL* Walking for leisure, *TRPA* Transport related physical activity, *TPA* Total physical activity; ᵃadjusted for age and sex; *$p < 0.05$; **$p < 0.01$; ***$p < 0.001$; bold, on borderline quality sidewalks have been associated with both walking and meeting physical activity recommendations elsewhere [28]. Here, neighborhoods with sidewalks on most streets were also associated with meeting 150 min per week or more of moderate-vigorous-physical activity [29]. In another study, lack of sidewalks was inversely associated with walking for leisure [30]. A possible explanation for these inconsistencies is that in some cities, sidewalks may serve more as a barrier than they do as a facilitator for walking. Sidewalks can be of poor quality and badly maintained and when combined with overcrowding, a person's ability to use them and the enjoyment of doing so is reduced [30].

Our participants who indicated seeing pleasant scenery (interesting things) while walking were more likely to reach 150 min per week or more of transport related physical activity, similar to the results in another study [19]. This implies that the good quality aesthetics in the neighborhood environment may positively influence the transport-related physical activity.

This study also noted that high volumes of traffic along the streets was associated with a lower likelihood of leisure-time physical activity and walking for leisure, which is similar to results found by studies in high-income countries [31]. For example, in the USA, neighborhoods that are safe from traffic were positively associated with walking [32]. Our results suggest that heavy traffic may be a barrier to physical activity and give preliminary evidence of the need to provide safe traffic environments to support physical activity in Africa.

Concerning crosswalks, this study observed that individuals who agreed that the crosswalks in their neighborhood helped walkers feeling safe crossing busy streets were also more likely to report sufficient levels of transported-related physical activity. Again, these results are consistent with those found in other studies [33]. Hence, having crosswalks in neighborhoods with high traffic volume may play an important role in determining the safety and physical activity levels of residents. The results of this study add to the existing, comparable literature by demonstrating that the association between crosswalks and physical activity meets public health recommendations for physical activity in urban and rural (African) settings.

Well-lit streets at night were positively associated with walking for leisure. These findings are significant in a South African context where crime rates are considered to be very high, and increasing with rapid urbanization. A study in the US found that feeling safe was linked to leisure time [33]. Similar results were reported in England [34] and Nigeria [11]. These pointedly demonstrate the need to assess perceived neighborhood attributes and their influence on physical activity [35]. However, limited information in the African context makes direct comparisons with other studies challenging. Perceived safety during the day is related to walking as most of individuals walk for transportation, especially among working class [11]. In addition, this relationship suggests that street lights could act as an indirect indicator for personal safety which in turn promotes walking for leisure as a choice rather than a need.

### Limitations and strengths of the study

Our study has some limitations. It relies on self-reported physical activity and perceived environment, rather than objectively measured physical activity and perceived built environment. Recall bias and imprecise assessment of physical activity could dilute some of the observed associations. In addition, our study is also affected by common sources bias between two self-reported measures which inflate the magnitude of associations. Furthermore, due to the non-availability of cluster-level data, we were unable to account for the clustering effect in the analysis. This has the undesirable effect of generating too conservative standard error, and increasing the risk of type 1 errors. Strengths of this study include the use of both NEWS and IPAQ, which makes it comparable with other studies, globally. Furthermore, this study included a sample population from urban and rural areas that has geographical variability in a perceived built environment.

## Conclusion

We found perceived built environment attributes to be associated with health related physical activity. Our findings provide baseline evidence for the need to provide walkable environments that will make it easier for South African adults to meet physical activity guidelines.

#### Abbreviation

IPAQ: International physical activity questionnaire; LTPA: Leisure time physical activity; NEWS: Neighborhood environmental walkability scale; PURE: Prospective Urban and Rural Epidemiology; TPA: Total physical activity; TRPA: Transport related physical activity; WL: Walking for leisure

#### Acknowledgements

The authors gratefully acknowledge the Population Health Research Institute, Hamilton Health Sciences and McMaster University, Hamilton, Canada and the Medical Research Council of South Africa for providing access to these data. Opinions, findings, conclusions and recommendations expressed are those of the authors and the funders accept no liability whatsoever in this regard.

#### Funding

This study was supported by Social Innovation in Public Health Impulse fellowship program for analysis, interpretation of data, transport and accommodation.

#### Availability of data and materials

The data used for the current analysis form part of the global PURE study and are therefore not available for sharing in isolation from the global dataset. However, the data is available for use in collaboration with local investigators. Interested parties may contact Prof Thandi Puoane on tpuoane@uwc.ac.za

**Authors' contributions**
PM, APK, EVL, ADV and TP were involved in the conception and design. PM conducted the analysis and interpretation. PM, ADV and APK were involved with interpretation and wrote the first draft. All of the authors were involved with drafting and revising and final approval.

**Competing interests**
The authors declare that they have no competing interest.

**Consent for publication**
No applicable.

**Ethics approval and consent to participate**
The study was conducted according to the Helsinki principles [36]. The Senate Higher Degrees committee, Research Committees of the University of the Western Cape, South Africa and the Population Health Research Institute, Canada approved this study (Registration #13/6/18). A consent form was signed by all the participants.

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Received: 10 March 2016 Accepted: 13 February 2017
Published online: 20 February 2017

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# CHAPTER 5

**Association between perceived built environment and prevalent hypertension among South African adults**

Hindawi Publishing Corporation
Advances in Epidemiology
Volume 2016, Article ID 1038715, 11 pages
http://dx.doi.org/10.1155/2016/1038715

Hindawi

*Research Article*

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

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Received 23 February 2016; Accepted 19 May 2016

Academic Editor: Masahito Fushimi



*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 ≥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% ($n = 46\,888$) of all deaths and 2.4% ($n = 390\,860$) 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 ($<18.5\,kg/m^2$), normal weight ($18.5$–$<25\,kg/m^2$), overweight ($25$–$<30\,kg/m^2$), and obese ($>30\,kg/m^2$).

*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 ≥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 *nearest* businesses or facilities if you *walked* to them?<br>(i) Groceries<br>(ii) Clothes shop<br>(iii) Fruits and vegetables<br>(iv) Restaurant<br>(v) Bank<br>(vi) Video shop |
| 02 | Land use-access | I can do most of my shopping at local stores<br>Stores are within easy walking distance of my home<br>There are many places to go within easy walking distance of my home<br>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<br>There are many four-way intersections in my neighborhood<br>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<br>The sidewalks in my neighborhood are well maintained<br>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<br>There are many interesting things to look at while walking in my neighborhood<br>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<br>There is so much traffic along nearby streets that it makes it difficult or unpleasant to walk in my neighborhood<br>The crosswalks in my neighborhood help walkers feel safe crossing busy streets |
| 07 | Safety from crime | My neighborhood streets are well lit at night<br>The crime rate in my neighborhood makes it unsafe to go on walks during the day<br>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 ($n = 510$) Number (%) | Male ($n = 161$) Number (%) | $p$ value | All ($n = 671$) Number (%) |
|---|---|---|---|---|
| *Gender* | | | | |
| Female | | | | 510 (76.0) |
| Male | | | | 161 (24.0) |
| *Age* | | | 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) |
| *Marital status* | | | **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) |
| *Education status* | | | 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) |
| *Occupation* | | | 0.118 | |
| Less skilled | 75 (14.7) | 129 (80.1) | | 564 (84.1) |
| Homemaker | 435 (85.3) | 32 (19.9) | | 107 (15.9) |
| *Ethnicity* | | | 0.240 | |
| African | 506 (99.2) | 158 (98.1) | | 664 (99.0) |
| Coloured | 4 (0.8) | 3 (1.9) | | 7 (1.0) |
| *Location* | | | 0.915 | |
| Urban | 221 (43.3) | 69 (42.9) | | 290 (43.2) |
| Rural | 289 (56.7) | 92 (57.1) | | 381 (56.8) |
| *Selected CVD risk factors* | | | | |
| *Blood pressure ($M \pm SD$)** | | | | |
| 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) |
| *Self-reported hypertension* | | | **<0.001** | |
| No | 338 (66.3) | 134 (83.2) | | 472 (70.3) |
| Yes | 172 (33.7) | 27 (16.8) | | 199 (29.7) |
| *Screen-detected hypertension* | | | **<0.001** | |
| Normotension | 186 (55.0) | 38 (28.4) | | 224 (47.5) |
| Hypertension | 152 (45.0) | 96 (71.6) | | 248 (52.5) |
| *Any hypertension* | | | **0.003** | |
| No | 186 (36.5) | 38 (23.6) | | 224 (33.4) |
| Yes | 234 (63.5) | 123 (76.4) | | 447 (66.6) |
| *Self-reported diabetes* | | | 0.469 | |
| No | 466 (91.4) | 150 (93.2) | | 616 (91.8) |
| Yes | 44 (8.6) | 11 (6.8) | | 55 (8.2) |
| *BMI category* | | | **<0.001** | |
| Normal | 100 (19.6) | 107 (66.4) | | 207 (30.8) |
| Overweight | 127 (24.9) | 23 (14.3) | | 150 (22.4) |
| Obese | 283 (55.5) | 31 (19.3) | | 314 (46.8) |
| *Smoking* | | | **<0.001** | |
| No | 437 (85.7) | 70 (43.5) | | 507 (75.6) |
| Yes | 73 (14.3) | 91 (56.5) | | 164 (24.4) |
| *Alcohol use* | | | **<0.001** | |
| No | 448 (87.8) | 73 (45.3) | | 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 (%) |
|---|---|---|---|---|
| *Physical activity levels* | | | 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) |
| *Perceived built environment attributes* | | | | |
| *Land use mix-diversity* | | | 0.110 | |
| ≤20 min | 42 (8.2) | 20 (12.4) | | 62 (9.2) |
| ≥21 min | 468 (91.8) | 141 (87.6) | | 609 (90.8) |
| *Land use mix-access* | | | 0.160 | |
| Disagree | 381 (74.7) | 129 (80.1) | | 510 (76.0) |
| Agree | 129 (25.3) | 32 (19.9) | | 161 (24.0) |
| *Street connectivity* | | | 0.612 | |
| Disagree | 227 (44.5) | 68 (42.2) | | 295 (44.0) |
| Agree | 283 (55.5) | 93 (57.8) | | 376 (56.0) |
| *Infrastructure for walking/cycling* | | | 0.091 | |
| Disagree | 248 (48.6) | 66 (41.0) | | 314 (46.8) |
| Agree | 262 (51.4) | 95 (59.0) | | 357 (53.2) |
| *Aesthetics* | | | 0.082 | |
| Disagree | 318 (62.4) | 88 (54.7) | | 406 (60.5) |
| Agree | 192 (37.6) | 73 (45.3) | | 265 (39.5) |
| *Safety from traffic* | | | 0.490 | |
| Disagree | 263 (51.6) | 78 (48.8) | | 341 (50.8) |
| Agree | 247 (48.4) | 83 (51.6) | | 330 (49.2) |
| *Safety from crime* | | | 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 | *p* value | OR[a] | 95% CI | *p* value |
| *Gender* | | | | | | |
| Male (ref) | | | | | | |
| Female | **2.53** | 1.61–3.97 | **<0.001** | **2.43** | 1.41–4.17 | **<0.001** |
| *Age* | | | | | | |
| 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** |
| *Education level* | | | | | | |
| 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 |
| *Location* | | | | | | |
| Rural (ref) | | | | | | |
| Urban | **2.26** | 1.61–3.16 | **<0.001** | **1.74** | 1.03–2.92 | **0.038** |
| *BMI* | | | | | | |
| 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** |
| *Physical activity level* | | | | | | |
| <150 min/week (ref) | | | | | | |
| >150 min/week | 1.23 | 0.88–1.83 | 0.203 | 1.16 | 0.75–1.79 | 0.504 |
| *Land use mix-diversity* | | | | | | |
| ≤20 min (ref) | | | | | | |
| ≥21 min | **1.96** | 1.51–3.34 | **0.013** | **2.37** | 1.24–4.55 | **0.009** |
| *Land use mix-access* | | | | | | |
| Disagree (ref) | | | | | | |
| Agree | 1.31 | 0.88–1.96 | 0.182 | 0.79 | 0.43–1.44 | 0.436 |
| *Street connectivity* | | | | | | |
| Disagree (ref) | | | | | | |
| Agree | **0.53** | 0.37–0.74 | **<0.001** | 0.64 | 0.35–1.17 | 0.149 |
| *Infrastructure for walking/cycling* | | | | | | |
| Disagree (ref) | | | | | | |
| Agree | **0.65** | 0.46–0.90 | **0.011** | 0.95 | 0.53–1.72 | 0.871 |
| *Aesthetics* | | | | | | |
| Disagree (ref) | | | | | | |
| Agree | **0.71** | 0.51–0.90 | **0.049** | 0.84 | 0.51–1.37 | 0.479 |
| *Safety from traffic* | | | | | | |
| Disagree (ref) | | | | | | |
| Agree | **1.46** | 1.04–2.03 | **0.027** | 1.17 | 0.66–2.06 | 0.599 |
| *Safety from crime* | | | | | | |
| 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; [a]odds 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 |
| *Gender* | | | | | | |
| Male (ref) | | | | | | |
| Female | **0.44** | 0.28–0.68 | **<0.001** | **0.47** | 0.29–0.78 | **0.004** |
| *Age* | | | | | | |
| 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** |
| *Education level* | | | | | | |
| 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 |
| *Location* | | | | | | |
| Rural (ref) | | | | | | |
| Urban | **2.41** | 1.37–4.24 | **0.002** | **2.70** | 1.64–4.47 | **<0.001** |
| *BMI* | | | | | | |
| 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 |
| *Physical activity level* | | | | | | |
| <150 min/week (ref) | | | | | | |
| >150 min/week | 0.91 | 0.58–1.43 | 0.691 | 0.99 | 0.66–1.47 | 0.942 |
| *Land use mix-diversity* | | | | | | |
| ≤20 min (ref) | | | | | | |
| ≥21 min | 2.13 | 0.95–4.75 | 0.065 | 1.26 | 0.67–2.39 | 0.476 |
| *Land use mix-access* | | | | | | |
| Disagree (ref) | | | | | | |
| Agree | 0.98 | 0.55–1.73 | 0.930 | 1.02 | 0.61–1.72 | 0.928 |
| *Street connectivity* | | | | | | |
| Disagree (ref) | | | | | | |
| Agree | 0.55 | 0.30–1.01 | 0.053 | 0.72 | 0.42–1.23 | 0.226 |
| *Infrastructure for walking/cycling* | | | | | | |
| Disagree (ref) | | | | | | |
| Agree | 0.55 | 0.50–1.71 | 0.795 | 0.90 | 0.52–1.55 | 0.706 |
| *Aesthetics* | | | | | | |
| Disagree (ref) | | | | | | |
| Agree | 1.23 | 0.73–2.09 | 0.434 | 1.29 | 0.81–2.06 | 0.285 |
| *Safety from traffic* | | | | | | |
| Disagree (ref) | | | | | | |
| Agree | **1.92** | 1.07–3.43 | **0.029** | 0.63 | 0.38–1.06 | 0.079 |
| *Safety from crime* | | | | | | |
| 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; [a]odds 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.

## Acknowledgments

The authors would like to thank the Population Health Research Institute, Hamilton Health Sciences, and McMaster University, Hamilton, Canada; the Medical Research Council of South Africa and the National Research Foundation of South Africa for permission to analyse their data. This study was supported by Social Innovation in Public Health Impulse Fellowship Programme. Funding was for analysis, interpretation of data, transport, and accommodation.

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