



Associations of built environmental characteristics and physical activity in neighbourhoods of Accra, Ghana

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ABSTRACT

Background: There is increasing evidence from observations in Western countries that the characteristics of the built environment can influence the physical activity levels of residents, but little data is available from low and middle-income countries. The aim of this study is to explore the association between neighborhood types, built environment characteristics and the physical activity in Accra, Ghana.

Methods: A cross-sectional study was conducted in Accra, with 12 neighborhoods randomly selected on the basis of high and low values of residential density and socioeconomic status. Sociodemographic, household and neighborhood information was collected with Neighborhood Environment Walkability Scale questionnaire adapted for Africa (NEWS-A). Physical activity was assessed with the modified WHO Global Physical Activity Questionnaire and social cohesion with the Perceived Neighborhood Social Cohesion Questionnaire. Generalized linear model was performed to determine the association between neighborhood characteristics and residents' physical activity.

Results: There were significant differences in the built environment characteristics and physical activity of residents in different neighborhood types. Residents of high residential density and high socioeconomic status neighborhoods had the highest levels of physical activity, mainly due to work-related physical activity. Closer proximity of destinations and recreational facilities, greater street connectivity, better aesthetics, greater safety when walking and cycling and safety from crime were associated with increased physical activity levels among residents. Conversely, social cohesion demonstrated no significant association with physical activity.

Conclusion: The built environment of neighborhoods has been demonstrated to be strongly associated with the physical activity levels of residents of Accra, Ghana.

1. Introduction

Physical activity plays a crucial role in maintaining good health, preventing obesity and noncommunicable diseases. There is strong evidence that regular physical activity is associated with a reduced risk of morbidity and mortality of several chronic conditions including cardiovascular diseases, hypertension, type 2 diabetes, and several types of cancer (Samitz et al., 2011; Lee et al., 2012; Warburton and Bredin, 2017; Bourke et al., 2024). A review of the current literature indicates that all levels of physical activity, including those of light intensity, are associated with a lower risk of mortality. This relationship follows a dose-response pattern, meaning that there is a clear link between the amount of exercise and the reduced risk of mortality (Kyu et al., 2016; Ekelund et al., 2019).

Globally, it has been estimated that 1.8 billion adults, nearly one third (31%) of the world adult populations, are physically inactive. In other words, they fail to meet the global recommendations of a minimum of 150 min moderate intensity physical activity per week. (Strain et al., 2024). Physical inactivity levels vary between and within country-income groups, based on World Bank's income classification. In 2022, the prevalence of physical inactivity was 38% in lower-middle-income countries, 33% in high-income and 18% in low-income countries (World Health Organization, 2024).

In Ghana, the prevalence of physical inactivity among adults aged 18 and over was 21% in 2022, 18% of males and 24% of females (World Health Organization, 2022).

A significant increase in physical activity of the entire population can be promoted by targeted modifications in physical and social

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environment (Wang et al., 2023). Evidence suggests that favorable built environments could control noncommunicable diseases, create significant positive health outcomes while achieving sustainable development goals among individuals through physical activity (Sallis et al., 2020). Studies in Western countries have already shown that built environment constructs, such as residential density, crime, traffic safety, facilities and infrastructure that enable physical activity, play a crucial role in influencing physical activity levels. (Feng et al., 2010; Ferdinand et al., 2012; Mackenbach et al., 2014; Smith et al., 2017).

Improving the characteristics of built environments such as footpaths (provision and quality), safety (from traffic and crime) and aesthetics (clean, litter- and graffiti-free streets, presence of plants and trees) can potentially increase transport-related physical activity and has been considered a low-cost and effective way to improve health (Adams and Cavill, 2015; Smith et al., 2017). Longitudinal studies have also confirmed that improved street connectivity, access to destinations and public transport accessibility have led to increased walking for transport and recreation in urban areas of high-income countries (Bandara et al., 2025).

The impact of the built environment on physical activity, diet, obesity, and health in Africa has been less studied. Perceived neighborhood safety from crime and traffic was observed to be related to physical activity among adults in Nigeria (Oyeyemi et al., 2011). Others reported no associations between GIS-measured walkability and physical activity in South Africa (Isiagi et al., 2021). A recent systematic review on the associations between built environment constructs and physical activity among children and adolescents in Africa, which was based on 6 studies, revealed associations between traffic and crime safety and physical activity (Adebusoye et al., 2022).

The Neighborhood Environment Walkability Scale for Africa (NEWS-Africa) is an adapted and validated tool designed to assess perceptions of neighborhood environmental characteristics that influence physical activity behaviors in African settings. The tool was developed through a rigorous process of translation, cognitive testing, and psychometric validation, and modified from the original NEWS instrument to reflect the unique urban environments across the Africa continent (Oyeyemi et al., 2016, 2017). Common local destinations were incorporated into the land use mix scale, as were items on unpaved walking paths within pedestrian structures. A new scale was created to measure personal safety, and the aesthetics scale was extended to incorporate African characteristics. This measurement tool was already used in Nigeria to examine associations of built environment with sedentary time among older adults (Oyeyemi et al., 2019) and in South Africa to study the association between built environment, physical activity and BMI among adults and adolescents (Malambo et al., 2018; Wayas et al., 2023).

The aim of this study was to examine how neighborhood built environmental characteristics, as measured using the NEWS-Africa instrument, were associated with adults' physical activity in different neighborhoods of Accra, Ghana. This objective informed the following research questions: (1) how are neighborhood residential density and socioeconomic status related to residents' physical activity, (2) which built environmental characteristics are associated with adults' physical activity, and (3) how do these characteristics relate to different domains of physical activity? The study examines these relationships in an understudied African urban context characterized by informal development with low safety from traffic and crime, and limited pedestrian infrastructure, allowing assessment of whether findings largely derived from high-income, planned cities are transferable to such settings. The research focuses not only on transport-related and leisure-time physical activity, but also on work-related physical activity, which is more prevalent in many African cities. In addition, the study uses locally adapted measures of the built environment that reflect contextual realities missing from standard assessment tools. The findings provide context-specific evidence that is directly relevant to urban planning and public health policy in rapidly urbanizing African cities, addressing a

significant gap in the global evidence base.

This paper is organized as follows. The next section describes the study area, the study design, the data collection and the variables, and the statistical analysis. The results section presents the findings of the analysis, which are then discussed in relation to existing literature. The strengths and limitations of the study are also provided. The final section provides conclusions and policy implications.

2. Methods

2.1. Study area, neighborhood sampling design

We conducted a cross-sectional study within the Accra Metropolitan Assembly between the months of June and July 2023. The Accra Metropolitan Assembly has a resident population of over 1.6 million and receives approximately two million daily business commuters. Located in the capital region of Ghana, this is the most urbanised and densely populated area in the country, with an estimated urban population of 91.7% and over 1.57 million households. This makes it a suitable location for this study. The sampling of neighbourhoods was based on a combination of residential area density (RAD) and socioeconomic status (SES) at the neighborhood level. The residential area density of neighborhood was calculated considering the number of people per square km (Brownson et al., 2009). The socioeconomic status of neighbourhoods was based on the slum index. The slum index measures the proportion of urban population residing in slums, informal settlements or inadequate housing. The index is derived from four main types of shelter deprivation, as defined by UN-Habitat as an indicator of informality: lack of access to improved water and sanitation facilities, insufficient living area, and poor quality and durability of the structure. (UN-Habitat; Jankowska et al., 2012).

GIS data (shapefiles) on the slum index and residential area density of Accra's neighbourhoods were obtained through the kind generosity of Professor J. Weeks (Weeks et al., 2007), whose research team used Ghana, Population and Housing Census, 2010 census survey data. (Ghana, Population and Housing Census, 2010) Attribute tables containing data on slum index and residential density of neighbourhoods were exported into Excel tables by using Q-GIS 3.34 software (QGIS Development Team, 2023). We categorized the data from the Excel file into tertiles, where we selected the upper and lower tertiles, representing low and high socioeconomic status (SES) and low and high residential area density (RAD), respectively. We then stratified the neighbourhoods into four strata; high-SES/high-RAD, high-SES/low-RAD, low-SES/high-RAD, and low-SES/low-RAD. Fig. 1 shows the locations of the study areas, depicting neighborhood boundaries and different types. Three neighbourhoods were randomly selected from each strata representing the 4 types of neighbourhoods. Fifty households were systematically selected from each of the 12 neighbourhoods included in the sample, so that one in five households was selected. One adult from each of these households volunteered to participate in the study. The response rate was 81%. Required sample size were calculated by using simplified formula for proportion (Israel, 1992).

2.2. Data collection

Information on individual characteristics of participants was collected through an interview based survey conducted by researchers (EES, NA) and two trained research assistants. The surveys were carried out face-to-face at the participants' homes. Each eligible adult was given information about the study. All participants provided verbal informed consent, which was recorded electronically. Questions were asked to participants in English, or the local language and responses were recorded on tablets using Kobo software. (KoboToolbox, 2023). During the survey, the COVID-19 protocols were followed in accordance with the regulations in force at the time.

JOINT DISTRIBUTION OF SOCIOECONOMIC STATUS AND RESIDENTIAL AREA DENSITY IN ACCRA, GHANA SHOWING THE VARIOUS STUDY SITES

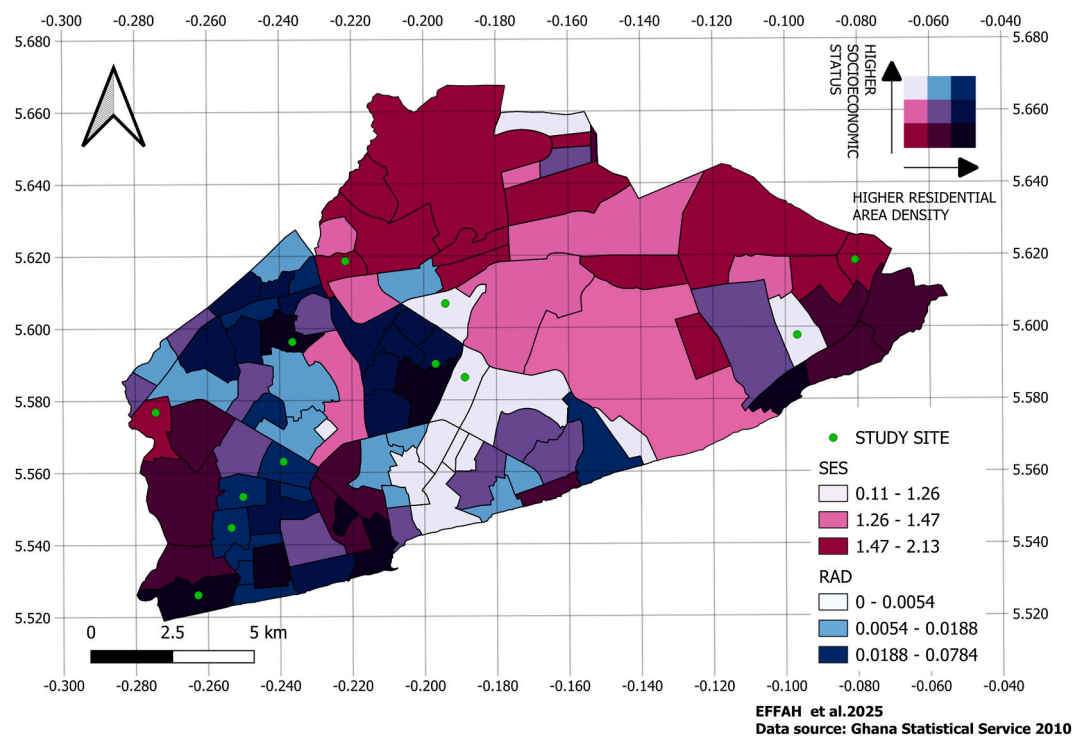


Fig. 1. Map showing neighborhood boundaries of Accra Metropolitan as well as the socioeconomic status and residential density of the neighborhoods, with the study locations labelled in green dots.

2.3. Sociodemographic variables

The sociodemographic variables considered in the analysis were age (categorized into groups), sex, educational level (none, primary, secondary and tertiary), and employment status (unemployed, employed or self-employed). Questions about the frequency of weekly use of private motorized transportation (owned or owned by someone else) were also included.

2.4. Physical activity

Physical activity was measured using modified WHO Global Physical Activity Questionnaire (Mathews et al., 2016). The content of the core questions is the same as the original GPAQ (World Health Organization, 2012), but with the addition of an activity table showing examples of activities of different ranges and intensities. This makes it useful in low- and middle-income countries. Work-related moderate and vigorous activity (work-related MVPA) consisted of 22 items and blank items for other nonspecific activities. Transport-related MVPA consists of two parts, walking and bicycling to and from places, with 8 items and blank items for all other unspecified activities. Leisure time MVPA included sports, fitness and other recreational activities, estimated separately for vigorous activities and moderate activities. The time spent with these activities per day was added to calculate work-related MPVA, transport-related MPVA, leisure time MPVA and total MPVA in min/day.

2.5. Perceived built environment

Perceived built environmental characteristics related to physical activity were assessed by the Neighborhood Environment Walkability Scale validated for Africa (NEWS-Africa) (Oyeyemi et al., 2016). This study deployed a total of 66 items from the original questionnaire, consisting of 9 computed subscales, to suit the analysis. These subscales

are land use mix – destinations (20 items) – recreation (4 items), connectivity of streets (5 items), places for walking and cycling (12 items), aesthetics (8 items), safety from traffic (6 items), safety from crime (4 items), personal safety (3 items), and child-related inquiries on stranger danger (3 items). Land use mix scales measured proximity to destinations in 5-point Likert scale (walking distance in minutes). Other scales measured agreement with statements in a 4-point Likert scale. In this analysis, higher values of the NEWS subscales indicate a higher land use mix (proximity to destinations), greater street connectivity, a more aesthetic appearance, greater security (safety while walking and cycling, protection from traffic and crime, and a greater sense of personal safety), and less stranger danger.

2.6. Neighborhood social cohesion

We collected information on social cohesion with an adapted form of the Perceived Neighborhood Social Cohesion Questionnaire Brief Form (P-NSC-BF). It is a nine-item scale that captures three aspects of neighborhood social cohesion, namely, trust (e.g. “Most people in this area can be trusted.”), attachment (e.g. “People in this area have a high degree of community spirit”) and tolerance (e.g. “People in this area are tolerant of others who are not like them”). Agreement with the statements was added and categorized into tertiles low, medium and high social cohesion (Dupuis et al., 2017).

2.7. Statistical analysis

We cleaned, coded, and analysed the data with IBM SPSS 26.0. Descriptive characteristics and comparisons by neighborhood type were performed. The distribution of the data is presented as percentages for categorical variables and as medians (IQRs) or means (SDs) for continuous variables. Differences by neighborhood types were tested using the Chi-square test and the Kruskal–Wallis test, pairwise comparison were

done by Dunn-Bonferroni test. Adjusted generalized linear model with Gamma distribution log link function and Robust Estimator was applied to determine the association between physical activity domains and built environmental characteristics and neighborhood types. The model selection was based on a comparative evaluation of fit indices, specifically the lowest AIC values and BIC values and highest log-likelihood values. Generalized linear model with a gamma distribution and a log link function and robust estimator showed the best model fit, as the dependent variables of the study were highly positively skewed and did not follow a normal distribution (Akram et al., 2023). The reported estimates are exponentiated coefficients (β), which indicate multiplicative changes in expected physical activity (min/day). Exp (β)s represent multiplicative change per 1-unit increase in the case of ordinal variables (built environmental characteristics) or expected mean ratios in the case of categorical variables. Significance levels were set by $p < 0.05$.

2.8. Ethics approval and consent to participate

Approval for the research protocols and methodology was provided by the Ethical Review Committee of the Ghana Health service. (GHS-ERC:022/03/23) Participants gave their written informed consent in each study population in accordance with the declaration of Helsinki.

3. Results

3.1. Sociodemographic characteristics of study participants

Table 1 (upper part) describes the sociodemographic variables included in this study by neighborhood type. The study sample consisted of 631 adults aged 18 years and older. Most of the respondents were young, with a median age of 34 years, and the proportion of females was higher (60.5%) than males (not seen in Table 1.). In general, more than 50% of the respondents were in the 18-35 age group across all neighborhood types. There were no significant differences in the proportion of females or the distribution of age groups between neighborhood types. Approximately 9-15% of participants reported no formal education, and two-thirds had a secondary education. There were no significant differences in educational level across neighborhood types, although 20.4% of respondents in high-SES/low-RAD neighborhoods had a tertiary education. Employment rates were highest in high-SES/high-RAD neighborhoods, self-employment was more common, and unemployment rates were highest in low-SES/high-RAD neighborhoods. There were also significant differences in vehicle use across neighborhood types; residents from low-RAD neighborhoods used private vehicles more frequently.

3.2. Physical activity of study participants

Moderate and vigorous physical activity (MVPA) related to work, transport, and leisure time was measured using the modified WHO Global Physical Activity Questionnaire. Table 1. (middle part) shows the daily MVPA of the study participants by neighborhood type. Work-related physical activity was the most dominant, with median values ranging from 10.35 to 72.4 min per day across neighborhood types. It was highest among participants from high-SES/high-RAD neighborhoods. Transport-related MVPA was highest among participants from high-SES/high-RAD neighborhoods. Leisure time (recreational) MVPA was generally very low (median 0.00 min/day) and lower in low-SES neighborhoods. The median total MVPA values ranged from 40.0 to 128.9 min per day. Specifically, participants from high-SES/high-RAD neighborhoods had, on average, twice as much physical activity as others.

Table 1

Sociodemographic variables, physical activity and neighborhoods' built environmental characteristics and social cohesion by neighborhood types.

Variables	High-SES/ High-RAD (n = 151)	High-SES/ Low-RAD (n = 152)	Low-SES/ High-RAD (n = 172)	Low-SES/ Low-RAD (n = 156)	p- value
Sociodemographic variables					
Age (median, IQR)	35 (25-49)	35 (26-45)	34 (26-45)	34.5 (25-45)	0.941
Sex (female %)	84 (56.0%)	89 (58.6%)	117 (68.0%)	91 (58.3%)	0.117
Educational level					
No education	18 (12.0%)	23 (15.1%)	16 (9.3%)	14 (9.0%)	0.163
Primary	19 (12.7%)	14 (9.2%)	18 (10.5%)	19 (12.2%)	
Secondary	93 (62.0%)	84 (55.3%)	118 (68.6%)	105 (67.3%)	
Tertiary	20 (13.3%)	31 (20.4%)	20 (11.6%)	18 (11.5%)	
Employment					
Unemployed	28 (18.7%)	44 (28.9%)	59 (34.3%)	34 (21.9%)	0.000
Employed	41 (27.3%)	53 (34.9%)	24 (14.0%)	48 (31.0%)	
Self-employed	81 (54.0%)	55 (36.2%)	89 (51.7%)	73 (47.1%)	
Vehicle use					
Few times	107 (71.3%)	122 (80.3%)	118 (68.6%)	130 (85.5%)	0.001
Most times	43 (28.7%)	30 (19.7%)	54 (31.4%)	22 (14.5%)	
Physical activity (min/day)					
Work-related MVPA	72.4 (10.0-235) ^{2,3,4}	29.6 (0.0-99.3) ¹	26.4 (0.0-118) ¹	10.4 (0.0-96.1) ¹	0.000
Transport-related MVPA	8.4 (0.0-39.0) ⁴	2.9 (0.0-42.9)	2.0 (0.0-36.8)	0.0 (0.0-10.4) ¹	0.001
Leisure time MVPA	0.0 (0.0-8.5) ^{3,4}	0.0 (0.0-8.6) ^{3,4}	0.0 (0.0-0.0) ^{1,2}	0.0 (0.0-0.0) ^{1,2}	0.000
Total MVPA	128.9 (27.1-351) ^{2,3,4}	64.6 (0.0-161) ¹	63.2 (0.0-188) ¹	40.0 (0.0-132) ¹	0.000
Neighborhood built environmental characteristics*					
Land use mix (1-5)					
Destination	3.5 (3.1-3.8) ²	3.1 (2.5-3.6) ^{1,4}	3.3 (2.9-3.7)	3.4 (3.1-3.7) ¹	0.000
Recreation	3.0 (2.6-4.0) ³	3.0 (2.0-4.0) ³	2.0 (1.5-3.0) ^{1,2,4}	3.0 (2.3-4.0) ³	0.000
Connectivity (1-4)	3.4 (3.4,3.6) ^{2,3,4}	3.1 (2.8-3.4) ^{1,3,4}	3.4 (3.2-3.4) ^{1,2}	3.4 (2.8-3.4) ^{1,2}	0.000
Aesthetics (1-4)	2.6 (1.9-3.0) ^{2,3}	3.0 (2.6-3.6) ^{1,3,4}	2.0 (1.1-2.9) ^{1,2,4}	2.7 (2.1-3.0) ^{2,3}	0.000
Safety (1-4)					
Walking, cycling	2.3 (1.9-2.8) ^{2,3,4}	2.0 (1.7-2.6) ¹	2.0 (1.5-2.6) ¹	2.2 (1.5-2.8) ¹	0.000
Traffic	2.0 (1.7-3.0) ³	2.3 (2.0-2.8) ^{3,4}	1.8 (1.3-2.0) ^{1,2,4}	2.0 (1.8-2.3) ^{2,3}	0.000
Crime	2.0 (1.3-3.0) ^{2,3}	2.0 (2.0-3.0) ^{1,3,4}	1.8 (1.0-2.0) ^{1,2}	2.0 (1.0-2.8) ²	0.000
Personal	3.0 (3.0-3.7) ³	3.0 (2.7-3.3) ³	3.0 (2.7-3.0) ^{1,2,4}	3.0 (2.7-3.3) ³	0.000
Stranger danger (1-4)	2.0 (1.7-3.0)	2.0 (2.0-2.3)	1.8 (1.0-2.0) ⁴	2.0 (1.0-2.3) ³	0.002
Neighborhood social cohesion					
Low	35 (23.3%)	39 (25.7%)	57 (33.1%)	68 (43.6%)	0.000
Medium	41 (27.3%)	66 (43.4%)	31 (18.0%)	46 (29.5%)	
High	74 (49.3%)	47 (30.9%)	84 (48.8%)	42 (26.9%)	

Values are presented as numbers and percentages (%), and medians with IQR percentiles (25%-75%). Differences in the distribution of the variables among neighborhood types were tested using the Chi-square and Kruskal-Wallis tests, pairwise comparison were done by Dunn-Bonferroni test.

*Neighborhood built environmental characteristics: Higher values indicate a higher land use mix (proximity to destinations), greater street connectivity, a

more aesthetic appearance, greater security (safety while walking and cycling, protection from traffic and crime, and a greater sense of personal safety), and less stranger danger.

Superscript numbers refer to the neighborhood type(s) with which there is a significant difference. 1 = High-SES/High-RAD, 2 = High-SES/Low-RAD, 3 = Low-SES/High-RAD, 4 = Low-SES/Low-RAD. SES socioeconomic status, RAD residential area density.

3.3. Built environmental characteristics and social cohesion of neighborhoods

Table 1 (lower part) summarizes the perceived environmental characteristics measured by using the Neighborhood Environment Walkability Scale for Africa (NEWS-Africa). Various destinations were generally close in proximity, within walking distance in neighborhoods, indicating a high land use mix. Proximity to recreational facilities was lower, being lowest in low-SES/high-RAD neighborhoods. The connectivity of streets was generally good but somewhat lower in high-SES/low-RAD neighborhoods. Neighborhood aesthetics were usually rated as low but somewhat better in high-SES/low-RAD neighbourhoods. The presence and quality of walking and cycling facilities were reported to be low but slightly better in high-SES/high-RAD neighborhoods. Participants perceived overall low safety from traffic because of its high speed and volume, especially in low-SES/high-RAD neighborhoods. Safety from crime was generally perceived as low and was associated with the presence of gangs and crime, which were worst in low-SES/high-RAD neighborhoods. Personal safety was reported to be generally good because of the presence of people and lighting in the streets and the lack of stray animals. Parents perceived more danger from strangers to their children around the house in low-SES/high-RAD neighborhoods. The common street views of various neighborhoods are illustrated in Fig. 2.

3.4. Association of neighborhood types with physical activity

Association of neighborhood types, social cohesion and sociodemographic variables with physical activity (min/day) were statistically analysed with generalized linear model (Table 2.).

Among different neighborhood types, residents living in high-SES/

high-RAD neighborhoods had 2.62 times (95% CI 1.82-3.77) higher work-related physical activity, 2.40 times (95%CI 1.39-4.13) higher transport-related physical activity, and 2.69 times (95% CI 2.00-3.61) higher total physical activity than residents living in low-SES/low-RAD neighborhoods. Social cohesion in neighborhoods did not show significant association with physical activity.

Among sociodemographic variables, higher age did slightly decrease the involvement in transport-related physical activity. Females had 2.41 times (95% CI 1.86-3.13) higher work-related physical activity and 1.54 times (95% CI 1.25-1.90) higher total physical activity, while 0.14 times lower leisure time physical activity than males. Educational level did not show significant association with physical activity. However, employment and self-employment status were statistically significantly associated with work-related and total physical activity. Frequent vehicle use was associated with decreased physical activity (total, including work and leisure time MVPA).

3.5. Association of built environment characteristics and physical activity

The association of built environmental characteristics, social cohesion, neighborhood socioeconomic status and residential density, and participants' sociodemographic variables with physical activity domains (min/day) was statistically analysed using a generalized linear model. In Table 3 the exp. coefficients (exp. β) and 95% CIs are reported.

Among neighborhood built environmental characteristics land use mix, connectivity of streets, aesthetics, safety while walking and cycling and from traffic, and stranger dangers were associated with physical activity. Namely, participants from neighborhoods with closer proximity to destinations (shops, supermarket, pub, cinema, schools, library, clinics, pharmacy etc.) had 1.95 times (95%CI 1.43-2.66) higher work-related physical activity, 1.61 times (95%CI 1.03-2.53) higher transport-related physical activity and 1.67 times (95%CI 1.26-2.22) higher total physical activity than participants who on average lived further away from these destinations. People living in neighborhoods with better street connectivity were found to have higher levels of work-related, transport-related and total physical activity. Participants in these neighborhoods had 1.56 times (95% CI 1.10-2.22) higher work-related physical activity, 2.22 times (95% CI 1.38-3.58) higher



Fig. 2. Typical street views of different socioeconomic and residential density neighborhoods.

Table 2

Association of neighborhood types, social cohesion and sociodemographic variables with physical activity.

Variables	Work-related MVPA	Transport- related MVPA exp. β (95% CI)	Leisure time MVPA	Total MVPA
Neighborhood types				
Low-SES/ Low- RAD	1.00 Ref	1.00 Ref	1.00 Ref	1.00 Ref
High-SES/ High-RAD	2.62 (1.82–3.77)	2.40 (1.39–4.13)	135 (0.00 – 199)	2.69 (2.00–3.61)
High-SES/ Low-RAD	1.21 (0.83 – 1.76)	1.54 (0.90 – 2.61)	1.04 (0.29 – 3.70)	1.35 (0.98 – 1.86)
Low-SES/ High-RAD	1.23 (0.86 – 1.76)	1.44 (0.80 – 2.56)	0.49 (0.13 – 1.85)	1.35 (0.99 – 1.82)
Social cohesion				
Low	1.00 Ref	1.00 Ref	1.00 Ref	1.00 Ref
Medium	0.74 (0.58,1.02)	0.97 (0.59,1.58)	0.84 (0.36,1.97)	0.85 (0.65,1.10)
High	1.04 (0.76,1.43)	1.35 (0.87,2.10)	2.04 (0.69,6.01)	1.11 (0.86,1.42)
Sociodemographic variables				
Age	1.00 (0.99,1.00)	0.99 (0.98–0.99)	0.99 (0.99- 1.00)	1.00 (0.99- 1.00)
Sex				
Male	1.00 Ref	1.00 Ref	1.00 Ref	1.00 Ref
Female	2.41 (1.86–3.13)	0.87 (0.62- 1.21)	0.24 (0.10–0.54)	1.54 (1.25–1.90)
Education				
No education	1.00 Ref	1.00 Ref	1.00 Ref	1.00 Ref
Primary	0.68 (0.36- 1.29)	1.17 (0.58- 2.37)	11.60 (0.00- 61599)	0.94 (0.57- 1.56)
Secondary	0.92 (0.55- 1.54)	1.46 (0.80- 2.65)	1.73 (0.66- 4.50)	1.11 (0.74- 1.67)
Tertiary	0.79 (0.43- 1.45)	1.46 (0.69- 3.06)	610 (0.00- 9116)	1.09 (0.68- 1.75)
Employment				
Unemployed	1.00 Ref	1.00 Ref	1.00 Ref	1.00 Ref
Employed	1.78 (1.33–2.39)	1.16 (0.68- 1.99)	0.68 (0.26- 1.79)	1.54 (1.18–2.00)
Self employed	1.86 (1.38–2.52)	1.60 (0.97- 2.64)	1.34 (0.48- 3.68)	1.65 (1.28–2.14)
Vehicle use				
Not at all	1.00 Ref	1.00 Ref	1.00 Ref	1.00 Ref
Most times	0.67 (0.47–0.95)	0.76 (0.49- 1.18)	0.39 (0.11–1.35)	0.65 (0.49–0.87)

The associations of neighborhood types, social cohesion and sociodemographic variables with physical activity domains (min/day) were statistically analysed with generalized linear model with a gamma distribution and a log link function. The reported estimates are exponentiated coefficients (exp. β) and 95% CIs. Exp. (β) represent the ratio of group means relative to the reference values. Coefficients were adjusted for all variables simultaneously. Bold figures represent significant association.

MVPA moderate and vigorous physical activity, SES socioeconomic status; RAD residential density.

transport-related physical activity and 1.44 times (95% CI 1.08–1.92) higher total physical activity than those living in neighborhoods with poorer street connectivity. Better neighborhood aesthetics were associated with 1.49 times (95% CI 1.19–1.88) higher transport-related physical activity. Residents in neighborhoods with higher safety while walking and cycling were 5.90 times (95% CI 1.44–24.15) higher leisure time physical activity. Residents in neighborhoods with higher safety from traffic were 1.49 times (95% CI 1.04–2.13) higher transport-related physical activity. Less stranger danger (safety of children under 18 years) was associated with 26% decrease of transport-related physical activity (0.74, 95% CI 0.59–0.92).

High socioeconomic status of neighborhood was associated with increased work-related and total physical activity, while neighborhood residential density was associated with transport-related and total physical activity. Among sociodemographic variables increased physical activity were associated with females, employment and self-

Table 3

Association of built environmental characteristics, social cohesion, neighborhood residential density and socioeconomic status, and sociodemographic variables with physical activity.

Variables	Work- related MVPA	Transport- related MVPA exp. β (95% CI)	Leisure time MVPA	Total MVPA
Built environmental characteristics				
Land use mix				
Destination	1.95 (1.43–2.66)	1.61 (1.03–2.53)	0.53 (0.06- 4.36)	1.67 (1.26–2.22)
Recreation	0.86 (0.71- 1.05)	0.81 (0.64- 1.01)	1.04 (0.34- 3.14)	0.92 (0.79- 1.07)
Connectivity	1.56 (1.10–2.22)	2.22 (1.38–3.58)	0.61 (0.17- 2.18)	1.44 (1.08–1.92)
Aesthetics	0.95 (0.80- 1.13)	1.49 (1.19–1.88)	1.04 (0.43- 2.52)	1.08 (0.94- 1.25)
Safety				
Walking, cycling	1.12 (0.81- 1.54)	0.93 (0.66- 1.31)	5.90 (1.44–24.15)	1.26 (0.98- 1.63)
Traffic	0.97 (0.75- 1.26)	1.49 (1.04–2.13)	0.84 (0.36- 1.99)	1.05 (0.85- 1.31)
Crime	1.02 (0.85- 1.23)	1.10 (0.86- 1.42)	1.86 (0.75- 4.61)	1.07 (0.90- 1.26)
Personal	1.05 (0.73- 1.51)	1.50 (0.95- 2.38)	1.18 (0.05- 27.71)	0.99 (0.73- 1.34)
Stranger danger	0.90 (0.77- 1.07)	0.74 (0.59–0.92)	1.60 (0.28- 9.13)	0.97 (0.84- 1.14)
Neighborhood social cohesion				
Low	1.00 Ref	1.00 Ref	1.00 Ref	1.00 Ref
Medium	0.74 (0.52- 1.04)	1.05 (0.63- 1.75)	0.23 (0.04- 1.23)	0.79 (0.57- 1.08)
High	0.96 (0.63- 1.47)	0.86 (0.51- 1.45)	0.55 (0.06- 4.75)	0.93 (0.66- 1.31)
Neighborhood socioeconomic status				
Low	1.00 Ref	1.00 Ref	1.00 Ref	1.00 Ref
High	1.67 (1.19–2.36)	1.11 (0.69- 1.79)	1.08 (0.24- 4.78)	1.39 (1.01–1.93)
Neighborhood residential area density				
Low	1.00 Ref	1.00 Ref	1.00 Ref	1.00 Ref
High	1.27 (0.88- 1.83)	2.12 (1.36–3.29)	1.84 (0.36- 9.43)	1.40 (1.03–1.90)
Sociodemographic variables				
Age	1.00 (0.99- 1.00)	0.99 (0.99–0.99)	1.01 (0.62- 1.64)	1.00 (0.99- 1.00)
Sex				
Male	1.00 Ref	1.00 Ref	1.00 Ref	1.00 Ref
Female	2.49 (1.84–3.38)	0.89 (0.62- 1.28)	0.29 (0.05- 1.59)	1.53 (1.20–1.95)
Education				
No education	1.00 Ref	1.00 Ref	1.00 Ref	1.00 Ref
Primary	0.61 (0.31- 1.20)	1.53 (0.68- 3.43)	4.33 (0.07- 261.71)	0.90 (0.49- 1.63)
Secondary	0.69 (0.39- 1.20)	1.09 (0.56- 2.13)	2.33 (0.02- 241.62)	0.80 (0.50- 1.26)
Tertiary	0.65 (0.34- 1.25)	1.03 (0.45- 2.35)	17.08 (0.19- 1542)	0.83 (0.50- 1.39)
Employment				
Unemployed	1.00 Ref	1.00 Ref	1.00 Ref	1.00 Ref
Employed	1.72 (1.24–2.39)	1.52 (0.92- 2.54)	0.63 (0.04- 8.94)	1.47 (1.09–1.99)
Self- employed	1.70 (1.21–2.39)	1.55 (0.96- 2.49)	0.52 (0.07- 3.71)	1.51 (1.12–2.03)
Vehicle use				
Not at all	1.00 Ref	1.00 Ref	1.00 Ref	1.00 Ref
Most times	0.56 (0.38–0.82)	0.66 (0.42- 1.02)	0.56 (0.11- 2.87)	0.62 (0.44–0.87)

The association of built environmental characteristics, social cohesion, neighborhood socioeconomic status and residential density, and participants' sociodemographic variables with physical activity domains (min/day) was statistically analysed using a generalized linear model with a gamma distribution and a log link function. The reported estimates are exponentiated coefficients (exp. β) and 95% CIs. In the case of ordinal data (built environmental characteristics), exp (β) indicates multiplicative change per 1-unit increase in

expected physical activity (min/day). In the case of categorical variables, $\exp(\beta)$ indicates the ratio of group means relative to the reference. Coefficients were adjusted for all variables simultaneously. Bold figures represent significant associations.

MVPA, moderate and vigorous physical activity.

employment and vehicle use.

4. Discussion

The present study explored the association between built environmental characteristics and physical activity across neighborhoods among adults in Accra, Ghana. High socioeconomic-high residential density neighborhoods were associated with increased work-related and transport-related physical activity, with a 2.69 times higher total physical activity compared to low-SES/low-RAD neighborhoods. Built environmental characteristics like proximity to destinations, street connectivity, aesthetics, traffic and crime safety, and personal safety all strongly associated with work- and transport-related physical activity. It was observed that providing, maintaining, and separating sidewalks, crosswalks, and cycling routes were associated with increased leisure time physical activity.

Physical activity across neighborhood types was higher in High-RAD neighborhoods and was dominated by work-related physical activity and least dominated by leisure time physical activity. Our findings are in agreement with the results of a large analysis of domain specific physical activity in 104 countries, which found that physical activity at work/household is the main contributor to the total physical activity in 80 countries, particularly in lower income countries. (Strain et al., 2020). A recent review of studies conducted in Ghana revealed that most physical activity is acquired through active occupations and travel, while leisure time physical activity is low (Mensah et al., 2022).

We also observed that females engaged in more work-related physical activity and less leisure time physical activity compared to males. Women performed more physical activity related to domestic work, while men did less housework. Men were more likely to work as machine and equipment operators, in skilled agricultural and fishing roles, elementary occupations and managerial positions. Additionally, males participated in more recreational sports than females. Women in Ghana often perceive organized fitness facilities as too intense or demanding, associating them with professional male athleticism (Tuakli-Wosornu et al., 2014; Charway and Strandbu, 2024).

We found a strong positive association between high-SES/high-RAD neighborhoods and work-related physical activity. The majority of these neighborhoods in Accra are commercial areas, and most residents are employed or self-employed and engage in physically active work. In addition, our research demonstrated a positive association between transport-related physical activity and residential density in Accra, consistent with findings from studies conducted in Western societies. Living in high density environment could facilitate the attainment of the recommended 150 min physical activity per week. This finding was observed in 17 cities from 12 countries (Sallis et al., 2016). A recent study has demonstrated a correlation between high residential area density and increased physical activity in various regions of Stockholm County, Sweden (Svensson et al., 2017). It is reasonable to assume that high residential density neighborhoods offer a greater number of destinations in close proximity. Consequently, residents are likely to choose active transportation (walking or cycling) to reach various destinations. In contrast, a study conducted in a mega-city in eastern China revealed a negative association between residential density and physical activity (Wang et al., 2019).

Several studies have been done to identify the main built environmental attributes of physical activity in urban environments (Owen et al., 2004; Frank et al., 2006; Ding and Gebel, 2012). However most of the studies were conducted only in a few countries in North America, Europe and Australia. The IPEN study was formed to provide

international evidence by collecting data on built environment and physical activity using the same methodology from 12 countries on 5 continents (Kerr et al., 2013). These studies have been confirmed that built environmental attributes, perceived or GIS based, are strongly related to walking for transport and leisure (Sallis et al., 2020). A recent study conducted in eight Latin American countries also confirmed that perceived neighborhood built environment characteristics were associated with transport-related and leisure time physical activity among adults (Ferrari et al., 2020).

In Accra, Ghana we were able to show a strong association with land use mix-diversity (proximity to destinations), street connectivity, aesthetics, pedestrian infrastructure and safety from traffic with transport-related physical activity. While leisure time physical activity were very low among participant in all type of neighborhoods, we observed that pedestrian sidewalks and crosswalks was strongly associated with leisure time physical activity. Previous studies conducted in South Africa also revealed that various built environmental attributes were positively associated with physical activity domains (Malambo et al., 2017).

The findings of the present study must be interpreted in the context of some significant limitations. Conclusions about the causality of the observed associations cannot be drawn due to the use of cross-sectional data. The use of self-reported measures of perceived built environment and physical activity may have been prone to errors and bias in responses. It is also possible that we were not able to detect all the associations due to the relatively small sample size. The regression analysis between domain specific physical activity and the characteristics of built environment resulted in wide confidence intervals for leisure time physical activity in some cases, which might be due to very low levels of leisure time physical activity in the study population. This study did not examine whether the associations between the perceived built environment and physical activity vary depending on neighborhood type. This may limit the insight gained into built environmental influences that are specific to each neighborhood. The strength of this study is the inclusion of neighborhoods with different socioeconomic statuses and residential densities, which were randomly selected. We were able to measure the perceived built neighborhood characteristics with the internationally widely used NEWS questionnaire validated for the African environment. Physical activity was measured using the modified WHO GPAQ (Mathews et al., 2016), an extension of the original GPAQ that includes an activity table showing activities of different ranges and intensities. This table helped to more accurately estimate physical activity. Although the physical activity data are not directly comparable to those from the more commonly used IPAQ questionnaire, the GPAQ also estimates transport-related and leisure time physical activity. Including work-related physical activity, which includes home activities, made the total physical activity estimation more precise.

5. Conclusion

This study found significant association between built environmental characteristics and physical activity among adults in Accra, Ghana. Work-related physical activity was the dominant component of total physical activity levels, and was associated with high socioeconomic status-high residential density neighborhood. Our research provided evidence that built environmental characteristics such as proximity to destinations, street connectivity, aesthetics, safety from traffic and crime, and personal safety were all strongly correlated with work- and transport-related physical activity. Although leisure time physical activity was generally low among participants, it was strongly correlated with pedestrian infrastructure.

The findings of this study have several practical implications for urban planning and public health policy in Accra and other African cities. The present study highlights the need for comprehensive interventions across diverse neighborhood types. Improvements to the built environment, particularly in areas with low socioeconomic status are required. The positive associations between destinations, street

connectivity, aesthetics, traffic safety, and walking/cycling safety, and higher levels of physical activity, suggest that urban planners should prioritize mixed-use development and improved pedestrian infrastructure, as well as enhancing neighborhood safety and aesthetics. Increasing the number of destinations such as markets, shops, schools and public services within walking distance could encourage active travel and increase daily physical activity. Improving aesthetics and street connectivity through better road networks and traffic safety could also encourage daily walking and cycling. Additionally, improving security can address safety concerns that limit transport-related and leisure-time physical activity.

Ethics approval and consent to participate

The Ghana Health Service Ethics Board approved this study (GHS-ERC 022/03/23). Informed consent was obtained from all participants, and the methods were performed in accordance with the relevant guidelines and regulations. The participants gave their written informed consent to each study population in accordance with the Declaration of Helsinki.

Consent for publication

Not applicable.

CRedit authorship contribution statement

Emmanuel Sintim Effah: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Writing – original draft, Writing – review & editing. **Abraham Nai:** Data curation, Formal analysis, Investigation. **Helga Bárdos:** Conceptualization, Methodology, Project administration, Supervision, Writing – review & editing.

Declaration of interest statement

The authors declare that they have no competing interest.

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Data availability

Data will be made available on request.

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