Preventive Medicine Reports 35 (2023) 102330

Contents lists available at ScienceDirect

Preventive Medicine Reports

journal homepage: www.elsevier.com/locate/pmedr

Neighborhood environment and quality of life among community-living older adults in Nigeria: The moderating effect of physical activity

Adewale L. Oyeyemi [a,*], Sanda M. Kolo [a], Adetoyeje Y. Oyeyemi [a], Babatunji A. Omotara [b], Shuaibu J. Yahaya [b], James F. Sallis [c,d]

[a] Department of Physiotherapy, College of Medical Sciences, University of Maiduguri, Maiduguri, Borno State, Nigeria
[b] Department of Community Medicine, College of Medical Sciences, University of Maiduguri, Maiduguri, Borno State, Nigeria
[c] Herbert Wertheim School of Public Health and Human Longevity Science, University of California San Diego, La Jolla, CA, USA
[d] Mary MacKillop Institute for Health Research, Australian Catholic University, Melbourne, Australia

ARTICLE INFO

Keywords:
Built environments
Community health
Exercise
Geriatrics
Healthy ageing

ABSTRACT

Understanding how neighborhood environments are related to older adults' quality of life (QoL) and physical activity (PA) is important for public health actions on healthy ageing in sub-Saharan Africa. We examined associations of perceived neighborhood environment attributes with QoL among older adults in Nigeria and investigated the moderating effects of PA on these associations. We conducted a cross-sectional study of 353 older adults (mean age = 68.9 ± 9.1 years) selected from 5 high- and low-income communities in Maiduguri, Nigeria. QoL, attributes of the neighborhood environments and PA were self-reported using validated questionnaires. Multi-level models were used to examine the direct associations between neighborhood environment attributes and each of the four domains of QoL (physical health, psychological health, social relationships, and environmental health), as well as the moderating effects of leisure-time and total PA. Seven of nine neighborhood environment features were positively associated with multiple domains of QoL. Residential density, land-use diversity, land-use mix-access, walking infrastructure, traffic safety and 'overall walkability' were positively related to both or either physical health and environmental health QoL among those who are physically active. In contrast, walking infrastructure, traffic safety, and 'overall walkability' were negatively related to psychological health QoL among those *not* physically active. Our findings suggest being physically active moderates the association of neighborhood environments with QoL among Nigerian older adults. We suggest that designing age-friendly communities and simultaneously promoting PA may be needed to improve QoL and help prepare the Nigerian society for the predicted increase in the older adult population.

1. Introduction

Globally, the proportion of persons aged 65 or older is expected to increase from around 3.6% in 2022 to 6.1% in 2050 in the least developed countries (United Nations, 2022). In sub-Saharan Africa, the older adults population is projected to grow faster at rates above 3% per year and rise from 3% in 2022 to almost double in 2050 (United Nations, 2022). This anticipated increase in older adults population may pose a challenge to the public health system in sub-Saharan Africa, where the burden of non-communicable diseases and associated health care costs are already high across the age spectrum (Gouda et al., 2019). With Nigeria's population growing the most rapidly and projected to become the third largest in the world by 2050 (United Nations, 2022), the country will have a large population of older persons in the coming years. Thus, understanding the correlates of healthy ageing in Nigeria is important for planning effective public health action in the country (Omotara et al., 2015), and Africa more generally.

Quality of life (Qol) is a marker of healthy ageing (Raggi et al., 2016). Since older people tend to spend more time at home and in their local neighborhoods (Clarke and Nieuwenhuijsen, 2009), the promotion of healthy ageing through interventions focusing on neighborhood built environments has been advocated in recent years (World Health Organization, 2007; World Health Organization, 2015; Garin et al., 2014). Compared to substantial evidence from multiple systematic reviews and *meta*-analyses on the relationship of built environments to physical activity (PA) among older adults (Cerin et al., 2017; Barnett et al., 2017;

* Corresponding author at: College of Health Solutions, Arizona State University, Phoenix, AZ 85004, USA.
E-mail address: adewale.oyeyemi@asu.edu (A.L. Oyeyemi).

https://doi.org/10.1016/j.pmedr.2023.102330
Received 11 March 2023; Received in revised form 13 July 2023; Accepted 14 July 2023
Available online 17 July 2023
2211-3355/© 2023 Published by Elsevier Inc. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).

Moran et al., 2014), relatively few studies, mainly from high-income countries, have examined the relationship between built environments and the QoL of older people (Garin et al., 2014; Sugiyama et al., 2008; Sugiyama et al., 2009; Roswall et al., 2015).

There are indications that neighborhood environments may not only be a proximal predictor of QoL and well-being of older people (Sugiyama and Thompson, 2007), but some of the relations might be explained by outdoor and recreational PA, as well as by other personal factors (Sugiyama et al., 2009). For example, it is possible neighborhood environments that are unfavorable to outdoor engagement and social interaction among older adults may lead to less engagement in recreational PA and thus poor QoL. Because physically active and non-active older adults could have different mobility options and health status, it could be hypothesized that the association between neighborhood environments and QoL differ by PA status (Sugiyama et al., 2008; Morita et al., 2010; Takano et al., 2002). A more favorable neighborhood environment could be enjoyed more by older adults who are physically active (Barnett et al., 2017; Moran et al., 2014), and therefore may be expected to relate more to QoL (Sugiyama and Thompson, 2007). Yet, this research topic has generally been unstudied in low- and middle-income countries, where significant populations of ageing adults will reside in the coming decades (United Nations, 2022).

Given the different socio-cultural contexts and environmental factors (e.g., safety, land-use patterns) in Africa compared with high-income countries (Oyeyemi et al., 2016), it is important, from a public health perspective, to understand the relation of community environments with older adults' QoL, and how this relationship may depend on their PA. Such evidence can be used to inform the development of targeted interventions for promoting healthy ageing in African countries. The present study aimed to examine associations between perceived neighborhood environment features and QoL among older adults in Nigeria, and investigate whether these associations are moderated by PA. We hypothesized that: (1) perceptions of neighborhood environment attributes favorable for PA would be positively associated with QoL, and (2) those associations would be stronger among older adults who do more leisure and total PA.

2. Method

2.1. Study design and participants

The methodology including study setting, participants, procedure, and the neighborhood environment, and PA measures have been described fully in our previous publication (Oyeyemi et al., 2019). Briefly, cross-sectional data on self-reported QoL, neighborhood environments, and PA were collected from older adults (60 years of age or older) in Maiduguri, Nigeria. For the purpose of this study, participants were recruited from 2 high-SES/low-walkable and 3 low-SES/high-walkable neighborhoods that were purposively selected from 5 out of the 15 localities in Maiduguri. Final selection of neighborhoods was based on local knowledge, because pre-existing land-use data were not available. Neighborhood walkability classification was based on the criteria from the transportation literature, as previously described for the city of Maiduguri (Oyeyemi et al., 2012). Based on these components of walkability, low-SES neighborhoods are generally highly walkable and high-SES neighborhoods are generally lowly walkable in Maiduguri (Oyeyemi et al., 2012). Though prior studies of walkability and health outcomes selected neighborhoods to represent 4 types based on a 2 X 2 matrix of high/low walkability X high/low SES (Cain et al., 2021), this was not possible in the present study. In each of the selected neighborhoods, households were enumerated on site, and older adults living in every odd numbered house were invited through home visits to participate in the study. All participants completed the survey through interview in their homes. A sample size of 385 participants (77 from each of the five localities) was determined to be needed to detect a moderate to large effect size with more than 80% power (Cohen, 1988). Eligibility criteria were: (1) living within the identified neighborhood in the last 12 months, (2) 60 years and older, (3) not having any disability that interfered with walking, and (4) being willing to be interviewed in English or local languages (Hausa or Kanuri language). The overall completion rate of those contacted and eligible was 83%, with 353 surveys available for analysis. All participants provided signed informed consent, and the study was approved by the Human Research Ethics Committee of the University of Maiduguri Teaching Hospital, Nigeria.

2.2. Measures

The dependent variables were domains of QoL. The independent variables were perceived features of the neighborhood environment, and the moderators were leisure-time and total reported PA.

2.2.1. Dependent variables

Quality of Life. Data on QoL were collected with the World Health Organization Quality of Life (WHOQOL)-BREF questionnaire, which contained 26-items that profiled QoL in four domains: physical health, psychological health, social relationships, and environmental health (World Health Organization Quality of Life Group, 1998). Items were rated on a 5-point Likert scale. The domain scores were calculated as the mean of items within the domain. For descriptive and analytical purposes, domain scores were transformed linearly to a 0–100 scale. Scores were scaled in a positive direction (i.e., higher scores denoted higher QoL). The WHOQOL-BREF domains have good internal consistency (Cronbach's $\alpha >= 0.70$) and content validity ($r = 0.61–0.80$) and acceptable validity for discriminating known groups among older adults in low-and middle-income countries, including Africa (World Health Organization Quality of Life Group, 1998; Colbourn et al., 2012). Cronbach's alpha coefficient of WHOQOL-BREF in the present study was 0.89.

2.2.2. Independent variables

Neighborhood built environments. Perceived attributes of neighborhood environments were measured with the Neighborhood Environment Walkability Scale-Abbreviated (NEWS-A), consisting of 54 items that have been adapted to Nigeria (Oyeyemi et al., 2016; Oyeyemi et al., 2017). NEWS-A assessed eight perceived neighborhood environment features including: (1) Residential density; (2) Land-use mix–diversity (proximity to non-residential destinations); (3) Land-use mix–access (ease of access to services and places); (4) Street/road connectivity; (5) Infrastructure and safety for walking; (6) Aesthetics; (7) Traffic safety; and (8) Safety from crime. Apart from residential density and land-use mix-diversity subscales, the other six subscale scores were computed as means of 4-point response options, ranging from 1 (strongly disagree) to 4 (strongly agree). Residential density subscale score was a weighted sum of six items reflecting presence of dominant housing types, ranging from lowest density to highest density. Land-use mix-diversity subscale scores were determined by the reported time, ranging from 1- to 5-min to greater than 30-min, to walk from one's home to various types of destinations. All NEWS-A subscales were computed as the mean of responses to items in the scale, with responses coded (or reverse-coded) such that higher values indicated higher "walkability" of the environment. In addition, a total NEWS-A score (herein referred to as 'overall-walkability index') was constructed by combining the mean of the standardized scores of the eight NEWS-A subscales. The NEWS-A scales are valid and reliable among older adults in Nigeria (Oyeyemi et al., 2016; Oyeyemi et al., 2017).

2.2.3. Moderators

Physical activity. Recreational (leisure) PA and overall total PA were assessed with the Nigerian Hausa version of the International Physical Activity Questionnaire (IPAQ)-long form (Oyeyemi et al., 2014). Leisure PA was computed by summing the duration of minutes/week of reported walking and moderate- and vigorous-intensities PA spent in leisure time.

To identify those engaging in leisure PA, leisure PA was dichotomized as doing any minutes/week of leisure-time activities versus not doing any minutes/week (World Health Organization, 2020). To determine the estimate of total PA in a week, total duration (minutes/week) of reported PA across domains (housework + occupation + transportation + recreation/leisure) were summed. Sufficient overall PA was defined as 5 or more days of any combination of walking, moderate-intensity, or vigorous-intensity activities achieving a minimum total PA of at least 600 Metabolic Equivalent (MET)-minutes/week (https://www.ipaq.ki.se/scoring.pdf). Test-retest reliability (ICC = 0.38–0.82) and construct validity (r = 0.11– 0.29) of Hausa IPAQ-long form among Nigerian adults (including older people) were acceptable (Oyeyemi et al., 2014).

Covariates: As control variables we included sociodemographic characteristics. The participants' age, sex, marital status, education and employment were self-reported and categorized as appropriate (Table 1). Height and weight were directly measured, and body mass index (BMI) was calculated (kg/m^2). Participants were categorized into underweight (<18.5 kg/m^2), normal weight (18.5–24.9 kg/m^2), overweight (25.0–29.9 kg/m^2) and obese (≥30.0 kg/m^2).

Table 1
Sample characteristics and descriptive information of quality of life, physical activity and environmental attributes among older adults in Maiduguri, Nigeria, 2012.

Variables	Total Sample (N = 353)
Socio-demographics	
Age group (n, %)	
60–64 years	135 (38.2)
65–69 years	100 (28.3)
70 year or more	118 (33.4)
Body weight status (n, %)	
Underweight (<18.5 kg/m^2)	4 (1.1)
Normal weight (18.5–24.9 kg/m^2)	112 (31.7)
overweight (25.0–29.9 kg/m^2)	191 (54.1)
obese (≥30.0 kg/m^2)	46 (13.0)
Marital status (n, %)	
Married	252 (71.4)
Not married	101 (28.6)
Education (n, %)	
> Secondary school	88 (24.9)
Secondary school	45 (12.7)
Primary school	38 (10.8)
Never attended school	182 (51.6)
Employment (n, %)	
Formal (office work)	47 (13.3)
Self-employed	109 (30.9)
Retired	73 (20.7)
Unemployed	124 (35.1)
Neighborhood type (n, %)	
Low-SES/high walkable	181 (51.3)
High-SES/low walkable	172 (48.7)
Quality of life outcomes [a]	
Physical health	62.9 ± 9.5
Psychological health	51.5 ± 10.1
Social relationships	71.5 ± 16.7
Environment	62.7 ± 12.9
Environmental attributes [a]	
Residential density	802.34 ± 84.79
Proximity to destinations	2.88 ± 0.43
Access to services and places	3.82 ± 0.47
Street connectivity	2.94 ± 0.52
Walking infrastructure and safety	3.03 ± 0.43
Aesthetics	2.51 ± 0.59
Traffic safety	2.32 ± 0.53
Safety from crime	2.85 ± 1.02
Walkability index	−0.003 ± 2.61
Physical activity variables [b]	
Recreation/Leisure PA (min/wk)	0 (0–40)
Overall Total PA (min/wk)	190 (70–450)
Meeting Physical Activity Guidelines	
Engaged in Recreation/Leisure PA (n, %)	
Yes	102 (28.9)
No	251 (71.1)
Sufficient Overall PA (n, %)	
Yes	171 (48.4)
No	182 (51.6)

[a] = Values for quality of life outcomes and environmental attributes are Mean ± Standard Deviation; [b] = Because the physical activity variables were skewed, the median and Inter Quartile Range (25th and 75th percentile values) are tabled; SES = Socioeconomic status; PA = Physical activity.

2.2.4. Statistical analysis

Descriptive statistics were computed for all measures. Multi-level models (MLMs) were used to examine direct associations between neighborhood environment attributes (eight scales; independent variables) and each of the QoL outcomes (physical health, psychological health, social relationships, and environmental health; dependent variables), as well as the moderating effects of leisure PA (some leisure PA vs no leisure PA) and overall (total) PA (sufficient vs insufficient). MLMs can handle data where observations are not independent, correctly modeling correlated error, and account for dependency in error terms due to clustering (participants recruited from selected neighborhood units) (Garson, 2013). For main-effects of each QoL outcome, we estimated separate MLMs for each environment attribute (single environment-attribute models) adjusting for covariates and neighborhood types. The cross-product terms of PA (separately for leisure PA and total PA) × each environmental variable were entered into the models to examine the potential moderating effects of PA. Statistical significance was set at $P = 0.05$ for interpreting main effects and at $P < 0.10$ for interpreting moderating effects (Twisk, 2006). In case of significant interactions, separate models were run to interpret the direction of the moderating effects. Because there is evidence that the pattern of neighborhood environment features is more strongly related to health behaviors than individual items (Oyeyemi et al., 2017; Van Cauwenberg et al., 2013), additional models were run, separately, for each QoL domain and 'overall-walkability index'. All analyses were conducted using SPSS version 18 (Armonk, NY, USA).

3. Results

3.1. Sample characteristics

Socio-demographic characteristics, perceived environment attributes, QoL and PA levels of the participants are shown in Table 1. The sample consisted of 353 participants with mean age of 68.9 ± 9.1 years (range = 60–102 years). About 40.0% were women, 71.4% were married, and 58.8% were retired or unemployed. The mean BMI of participants was 26.5 kg/m^2 (SD = 4.0); 54.1% were overweight and 13.0% were obese. Participants reported highest QoL in social relationships (71.5 ± 9.5) and the lowest in psychological health (51.5 ± 10.1). The median time reported by the participants in leisure PA was 0.0 min/week, with 25% reporting ≤ 0 min/week and 25% reporting ≥ 40 min/week of leisure PA. The median time in total PA was 3.2 hr/week, with 25% of participants reporting ≤ 1.2 hr/week and 25% reporting ≥ 7.5 hr/week of overall PA. The reported mean time in leisure PA and total PA were 51.5 ± 113.3 min/week and 461.3 ± 911.9 min/week, respectively.

3.2. Neighborhood environmental attributes association with quality of life

Table 2 shows the main effects of neighborhood environment attributes on QoL. Physical health QoL was positively associated with residential density (b = 1.89, $P = 0.032$), land-use mix-diversity (b = 2.44, $P = 0.023$), land-use mix-access (b = 1.94, $P = 0.040$), infrastructure and safety for walking (b = 3.39, $P = 0.001$), and 'overall-walkability' (b = 0.42, $P = 0.003$). Psychological health QoL was negatively associated with ease of access to services and places (b = -2.14, $P = 0.039$), infrastructure and safety for walking (b = -2.69, $P = 0.022$), safety from traffic (b = -1.15, $P = 0.035$), and 'overall-walkability' (b = -0.52, $P =$

Table 2
Associations of environmental attributes with quality of life (Main effect) among older adults in Maiduguri, Nigeria, 2012.

	Physical health domain		Psychological domain		Social relationship domain		Environmental domain	
Environmental attributes	b	95% CI	b	95% CI	b	95% CI	b	95% CI
Residential density	**1.89***	**0.16, 3.63**	−1.74	−3.64, 0.16	0.79	−2.09, 3.67	1.52	−0.71, 3.75
Land-use mix diversity	**2.44***	**0.34, 4.55**	−0.20	−2.52, 2.11	**3.55***	**0.06, 7.03**	−0.69	−3.42, 2.04
Land- use mix access	**1.94***	**0.09, 3.79**	**−2.14***	**−4.18, −0.11**	1.67	−1.42, 4.75	0.18	−2.23, 2.59
Street connectivity	0.19	−1.45, 1.84	0.08	−1.74, 1.89	−1.43	−4.15, 1.29	0.32	−1.82, 2.59
Walking infrastructure and safety	**3.39****	**1.32, 5.47**	**−2.69***	**−4.99, −0.39**	2.07	−1.40, 5.55	**2.52***	**0.01, 5.25**
Aesthetics	−0.52	−1.98, 0.94	−0.75	−2.36, 0.86	0.88	−1.55, 3.30	0.64	1.26, 2.54
Traffic safety	−0.33	−1.94, 1.29	**−1.15***	**−2.22, −0.08**	−1.81	−4.43, 0.85	**2.07****	**0.87, 3.27**
Crime safety	0.27	−0.68, 1.22	−1.24	−3.04, 0.56	−0.66	−2.23, 0.91	0.73	−1.39, 2.86
Walkability index	**0.42***	**0.14, 0.70**	**−0.52****	**−0.82, −0.22**	0.16	−0.30, 0.63	**0.42***	**0.06, 0.78**

b = regression coefficient; 95% CI = 95% confidence intervals; *=Value significant at $P \leq 0.050$; **=Value significant at $P \leq 0.001$.

0.001). Environmental health QoL was positively associated with infrastructure and safety for walking (b = 2.52, $P = 0.045$), safety from traffic (b = 2.07, $P = 0.001$), and 'overall-walkability' (b = 0.42, $P = 0.023$). Social relationship QoL was positively associated only with land-use mix-diversity (b = 3.55, $P = 0.046$).

Table 3
Leisure physical activity and total physical activity specific effect on associations of environmental attributes with quality of life among older adults in Maiduguri, Nigeria, 2012.

	Physical health domain		Psychological domain		Environmental domain	
PA Specific Effect	b	95% CI	b	95% CI	b	95% CI
Residential density						
Some Leisure PA	**2.85***	**0.05, 5.66**	–	–	–	–
No Leisure PA	0.80	−1.89, 3.49	–	–	–	–
Sufficient Total PA	2.09	−0.21, 4.38	–	–	–	–
Insufficient Total PA	0.22	−3.45, 3.88	–	–	–	–
Land-use mix diversity			–	–	–	–
Some Leisure PA	**5.30****	**2.54, 8.06**	–	–	–	–
No Leisure PA	2.59	−1.11, 6.30	–	–	–	–
Sufficient Total PA	**6.34****	**3.01, 9.66**	–	–	–	–
Insufficient Total PA	**3.95***	**0.87, 7.03**	–	–	–	–
Land-use mix access			–	–	–	–
Leisure PA	**4.81***	**1.65, 7.97**	–	–	–	–
No Leisure PA	0.68	−1.84, 3.21	–	–	–	–
Sufficient Total PA	2.28	−0.10, 4.66	–	–	–	–
Insufficient Total PA	1.58	−1.42, 4.57	–	–	–	–
Street connectivity			–	–		
Some Leisure PA	1.09	−0.87, 3.05	–	–	−0.19	−3.95, 3.55
No Leisure PA	−2.45	−5.37, 0.47	–	–	−3.58	−8.22, 1.06
Sufficient Total PA	1.45	−0.82, 3.72	–	–	–	–
Insufficient Total PA	−0.24	−2.69, 2.22	–	–	–	–
Walking infrastructure & safety					–	–
Some Leisure PA	**4.72***	**1.26, 8.17**	–	–	–	–
No Leisure PA	1.95	−2.19, 6.09	–	–	–	–
Sufficient Total PA	**3.57***	**0.74, 6.39**	−2.11	−6.51, 2.27	–	–
Insufficient Total PA	1.47	−2.44, 5.38	**−3.32***	**−6.02,-6.22**	–	–
Aesthetics					–	–
Some Leisure PA	0.03	−2.71, 2.77	–	–	–	–
No Leisure PA	−1.79	−5.11, 1.54	–	–	–	–
Sufficient Total PA	−0.46	−2.68, 1.76	–	–	–	–
Insufficient Total PA	−1.37	−3.86, 1.13	–	–	–	–
Traffic safety					–	–
Some Leisure PA	−0.32	−2.45, 1.81	−0.07	−1.97, 1.82	**2.23***	**0.84, 3.62**
No Leisure PA	1.28	0.62, 3.17	**−1.26**	**−2.54, 0.01**	1.67	−0.55, 3.88
Sufficient Total PA	1.00	−0.43, 2.44	–	–	–	–
Insufficient Total PA	**−1.41***	**−2.78, −0.05**	–	–	–	–
Crime Safety	–	–	–	–	–	–
Some Leisure PA			–	–	–	–
No Leisure PA			–	–	–	–
Sufficient Total PA	−0.93	−3.12, 1.27	–	–	–	–
Insufficient Total PA	−0.39	−2.74, 1.95	–	–	–	–
Walkability index					–	–
Some Leisure PA	–	–	–	–	**0.73***	**0.26, 1.19**
No Leisure PA	–	–	–	–	0.29	−0.29, 0.88
Sufficient Total PA	–	–	−0.41	−0.85, 0.04	–	–
Insufficient Total PA	–	–	**−0.59***	**−1.18, −0.00**	–	–

b = regression coefficient; 95% CI = 95% confidence intervals; PA = Physical activity; *=Value significant at $P \leq 0.050$; **=Value significant at $P \leq 0.001$; - =Indicates no effect.

3.3. Interactions of physical activity on associations between neighborhood environment attributes and quality of life

The detailed results of interaction effect of recreational/leisure PA and total PA on associations of environmental attributes with QoL are shown in the Appendix A.

For physical health QoL, there was interaction effects of both leisure PA and total PA with each of residential density, land-use mix-diversity, land-use mix-access, street connectivity, infrastructure and safety for walking, aesthetics, and safety from crime. The association of higher residential density with better physical health QoL was stronger in older adults who engaged in leisure PA (b = 2.87, P = 0.046), with a marginally significant for those who were physically active overall (b = 2.09, P = 0.074) than those who were not active (Table 3). Compared to those who not did not engage in leisure PA, those who engaged in leisure PA showed 2.9 points higher physical health QoL for each one-unit increment in residential density. Land-use mix-diversity was related to better physical health QoL only in older adults who engaged in leisure PA (b = 5.30, P = 0.001). Older adults who were physically active overall had 6.3 points higher, and those not active overall had 3.9 points higher physical health QoL for each one-unit increment in land-use mix-diversity. Land use-mix-access was related to better physical health QoL in those who engaged in leisure PA (b = 4.81, P = 0.003) and marginally better physical health QoL among those who were physically active overall (b = 2.28, P = 0.060). Compared to those physically inactive overall (1.6 point higher), participants who were physically active showed 2.3 point higher physical health QoL for each one-unit increment in land use-mix access. Better perceived walking infrastructure was related to better physical health QoL in those who engaged in leisure PA (b = 4.72, P = 0.008) and were physically active overall (b = 3.57, P = 0.014). Better perception of traffic safety was related to lower physical health QoL only among older adults who were physically inactive overall (b = -1.41, P = 0.042) (Table 3).

For psychological health QoL, there were significant effect modifications of total PA with walking infrastructure and 'overall-walkability', and leisure PA with traffic safety. Better perceptions of walking infrastructure (b = -3.32, P = 0.016) and higher 'overall-walkability' (b = -0.59, P = 0.050) were negatively associated with psychological health QoL more among those who were physically inactive overall than those who were active. Better perception of traffic safety was marginally negatively associated with psychological health QoL among older adults who did not engage in leisure PA (b = -1.26, P = 0.052) (Table 3).

For environmental health QoL, there were significant effect modifications of leisure PA with traffic safety and 'overall-walkability'. Environmental health QoL was positively associated with safety from traffic (b = 2.23, P = 0.002) and 'overall-walkability' (b = 0.73, P = 0.003) only in older adults who engaged in leisure PA (Table 3).

4. Discussion

Similar to findings from studies in high-income countries (Garin et al., 2014; Sugiyama et al., 2008; Sugiyama et al., 2009; Roswall et al., 2015), the present study suggested that multiple neighborhood environment features were related to better QoL of older adults in Nigeria. Attributes of built environments, including safety from traffic, having safe parks and low street noise have similarly been associated with health-related QoL of older adults in the middle-income country of Colombia (Parra et al., 2010). The strongest evidence in the present study was that living in proximity to commonly-used destinations (i.e., mixed-land use) was positively related to both physical health and social relationship QoL. It was also notable that walking infrastructure and 'overall-walkability' were positively related to both physical health and environmental health QoL. Living within walking distance of shops and services and having safe walking infrastructure allow older adults to live independently and remain engaged in their communities, which would be expected to support higher QoL. Living in higher-density areas was positively related to physical health QoL, perhaps because of the increased opportunities for maintaining interactions and relationships.

There was mixed evidence for the 'overall-walkability', perceived traffic safety, and walking infrastructure. It was expected these three environmental variables would be positively related to several QoL domains, but the pattern of negative associations with psychological QoL is difficult to interpret and justifies further study. Perhaps the confounding of walkability and socioeconomic status in the study neighborhoods could explain this finding, because lower-income participants could be expected to have worse psychological QoL. Future studies should attempt to disentangle walkability and SES effects related to psychological QoL. It was notable perceived crime safety was not related to any of the QoL domains, suggesting that in this region of high crime, including terrorism (Oladipo, 2013), older adults have learned to cope with a chronically stressful situation. Overall, there was weak evidence that neighborhood environment variables previously shown to be related to PA in this sample (Oyeyemi et al., 2019) were directly related to the QoL domains, except for positive effects of living in neighborhoods with good access to shops and services.

4.1. The moderating effects of physical activity on the association between neighborhood environment attributes and quality of life

The effect modification results provided a compelling pattern of results indicating PA may improve the positive impact of neighborhood environment attributes on older adults' QoL. Eight of eleven significant effect modification tests showed associations between environment characteristics and QoL were significantly positive only among those who were physically active. The other findings were that walking infrastructure, traffic safety and 'overall-walkability' were negatively related to psychological health QoL only among older adults *not* physically active. It is unclear why living in neighborhood with walking infrastructure and traffic safety would be related to poorer QoL among any group, but the potential for confounding with SES should be considered. It also is possible the inactive older adults were too physically limited to go out and enjoy their favorable neighborhood environments, and they were somewhat depressed by their situation. Previous evidence suggests perceptions of neighborhood environments can be different, depending on how physically active or inactive people are, with those who are inactive likely to be spending less time outdoors, and be less familiar with their neighborhood environments (Humpel et al., 2004). Thus, PA could be a confound for neighborhood perceptions. Perhaps, combined interventions to improve neighborhood environments and simultaneously promote PA may be needed to enhance QoL among Nigerian older adults.

Because PA significantly moderated eleven of the relations between neighborhood environment attributes and QoL, this is a compelling pattern of evidence that favorable neighborhood environments were positively related to QoL of Nigerian older adults only among those who were physically active. Traffic safety was an effect modifier for 3 QoL domains, suggesting older adults who take advantage of safe traffic situations experience robustly better QoL. In the present study, PA was a significant effect modifier for all QoL domains except social relationship QoL. Perhaps, unmeasured cofounders such as age-related disease and disability that might decrease physical functioning and worsen social isolation in old age could explain the lack of effect modification of PA on associations of neighborhood environments with social relationship QoL. Previous studies suggest greater neighborhood satisfaction and opportunities to engage in social activities could partly explain some of the observed association between environment features and QoL of older adults (Richard et al., 2008; White et al., 2010).

4.2. Strengths and limitations

Whilst our study has some strengths, including a focus on an understudied population (African older adults) and utilization of valid

and widely used measures that facilitate international comparison, interpretations should be made in the light of some important limitations. First, the study was cross-sectional and conducted in one city, precluding causal interpretations and generalization to African older adults from other settings. Second, the cross-sectional design means alternative explanations should be considered. Reverse causation is a possibility. Instead of living in a walkable neighborhood being a cause of higher QoL, perhaps older adults with high QoL move to neighborhoods where they can take advantage of being able to walk to places for shopping and socializing. This possibility is directly related to the common concern with "self-selection" in studies of built environments that people choose environments that match their pre-existing preferences, which discounts the impact of environments on people's lives. Self-selection could not be included in present analyses, which is a limitation. Prior studies of neighborhood built environments and PA statistically adjusted for self-selection, and the general finding is that self-selection plays a role but not fully account for explanatory associations of walkability and other built environment variables with PA (Boone-Heinonen et al., 2021; Mokhtarian and Cao, 2008). Residential selection processes may differ across countries and regions. For example, in Maiduguri and other African cities, residential selection options are limited for low-income residents. Living in multi-generational households or living very near family may be a higher priority than in many high-income countries, a characteristic likely to alter the dynamics of self-selection in low- and middle-income countries. Nevertheless, we recommend future studies on neighborhood environments and QoL include measures and analyses related to self-selection. Third, the unavoidable confounding of neighborhood walkability and SES inherent in Maiduguri presents substantial challenges to interpretation. Replication in other cities in low-income countries that are able to stratify neighborhoods by both built environments and SES are needed. Fourth, given the overrepresentation of men in the present study, there is a possibility of selection bias. Fifth, the use of self-report measures may be subject to recall bias and social desirability. Over-reporting due to social desirability, leading to misclassification and overestimation of the prevalence of PA, has been reported specifically for the IPAQ (Rzewnicki et al., 2003; Ainsworth et al., 2006). Sixth, our data and analytic plan precluded a mediation analysis that could allow for estimates of the direct and indirect effects of the environments on QoL by fitting models with and without PA. However, we believe the reported analyses of moderating effects of PA adds important data to the field, which is largely unstudied in the region. The findings provide preliminary evidence that improvement to environmental characteristics designed to promote PA could simultaneously be a means for improving the QoL of older adults in Nigeria.

4.3. Future directions

Future studies that build on these findings and explore PA as a mediator of environments and QoL among older adults in the African populations are needed. Ideally, such studies should use a prospective design. We recommend future studies use appropriate measures of "self-selection" for African populations. Studies are needed that apply geospatial and mixed methods (including qualitative data collection) approaches to better understand why some neighborhood environment features like good walking infrastructure and better traffic safety would be related to poorer QoL among inactive older adults compared to their peers who are physically active.

5. Conclusions

Consistent with our hypotheses, multiple activity-supportive environmental attributes were related to 3 of the 4 domains of QoL. The primary finding was that having many shops and services within easy walking distance of homes, indicating mixed-land use, was positively related to multiple domains of QoL. Activity-supportive environment attributes, such as more diversity of destinations, good access to services, good aesthetics, higher residential density, more connected streets and safety from traffic, have already been linked with physical, psychological, and social health benefits, as well as favorable economic and environmental sustainability effects (Sallis et al., 2015; Salvo et al., 2021). Also as hypothesized, we found the PA status of Nigerian older adults moderated the association of some neighborhood environment factors with QoL. Leisure PA was a more consistent moderator than total PA, which is logical because leisure activities are done in specific places in neighborhoods, while occupational and household activities usually do not depend on the neighborhood built environment. Present findings demonstrate the potential for activity-supportive neighborhoods to enhance QoL among Nigerian older adults who are physically active. Our findings suggest that age-friendly and activity-supportive community design and promotion of PA are important priorities that could help prepare Nigerian society for more successful healthy ageing, which will be a higher priority given predicted increase in the older adult population in Africa and the rest of the world.

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

Acknowledgements

We thank Dr. Terry Conway for her help with developing the syntax for running the multi-level models in SPSS.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.pmedr.2023.102330.

References

Ainsworth, B.E., Macera, C.A., Jones, D.A., Reis, J.P., Addy, C.L., Bowles, H.R., Kohl, H. W., 2006. Comparison of the 2001 BRFSS and the IPAQ physical activity questionnaires. Med. Sci. Sports Exerc. 38 (9), 1584–1592. https://doi.org/10.1249/01.mss.0000229457.73333.9a.

Barnett, D.W., Barnett, A., Nathan, A., Van Cauwenberg, J., Cerin, E., 2017. Built environmental correlates of older adults' total physical activity and walking: A systematic review and meta-analysis. Int. J. Behav. Nutr. Phys. Act. 14 (1), 103. https://doi.org/10.1186/s12966-017-0558-z.

Boone-Heinonen, J., Gordon-Larsen, P., Guilkey, D.K., Jacobs, D.R., Popkin, B.M., 2021. Environment and physical activity dynamics: The role of residential self-selection. Psychol Sport and Exerc. 12 (1), 54–60. https://doi.org/10.1016/j.psychsport.2009.09.003.

Cain KL, Salmon J, Conway, TL, et al. The International Physical Activity and Built Environment Study of Adolescents: IPEN Adolescent design, protocol, and measures. BMJ Open. 2021;11:e046636. doi:10.1136/bmjopen-2020-046636.

Cerin, E., Nathan, A., Van Cauwenberg, J., Barnett, D.W., Barnett, A., 2017. The neighbourhood physical environment and active travel in older adults: A systematic review and meta-analysis. Int. J. Behav. Nutr. Phys. Act. 14 (1), 15. https://doi.org/10.1186/s12966-017-0471-5.

Clarke, P., Nieuwenhuijsen, E.R., 2009. Environments for healthy ageing a critical review. Maturitas 64 (1), 14–19. https://doi.org/10.1016/j.maturitas.2009.07.011.

Cohen, J.A., 1988. Statistical Power Analysis for the Behavioural Sciences, 2nd ed. Lawrence Erlbaum Associates, Hillsdale, NJ.

Colbourn, T., Masache, G., Skordis-Worrall, J., 2012. Development, reliability and validity of the Chichewa WHOQOL-BREF in adults in Lilongwe. Malawi. BMC Research Notes. 5, 346. https://doi.org/10.1186/1756-0500-5-346.

Garin, N., Olaya, B., Miret, M., Ayuso-Mateos, J.L., Power, M., Bucciarelli, P., Haro, J.M., 2014. Built environment and elderly population health: A comprehensive literature review. Clin. Pract. Epidemiol. Ment. Health 10 (1), 103–115. https://doi.org/10.2174/1745017901410010103.

Garson G.D. Hierarchical Linear Modeling: Guide and Applications Thousand Oaks, CA: SAGE Publications, Inc.; 2013. doi:10.4135/9781483384450.

Gouda HN, Charlson F, Sorsdahl K, et al. Burden of non-communicable diseases in sub-Saharan Africa, 1990–2017: results from the Global Burden of Disease Study 2017. The Lancet Global Health. 2019;7(10):e1375–e1387. doi.org/10.1016/s2214-109x(19)30374-2.

Humpel, N., Marshall, A.L., Leslie, E., Bauman, A., Owen, N., 2004. Changes in neighborhood walking are related to changes in perceptions of environmental attributes. Ann. Behav. Med. 27 (1), 60–67. https://doi.org/10.1207/s15324796abm2701_8.

Mokhtarian, P.L., Cao, X., 2008. Examining the impacts of residential self-selection on travel behavior: A focus on methodologies. Transp. Res. B Methodol. 42 (3), 204–228. https://doi.org/10.1016/j.trb.2007.07.006.

Moran, M., Van Cauwenberg, J., Hercky-Linnewiel, R., Cerin, E., Deforche, B., Plaut, P., 2014. Understanding the relationships between the physical environment and physical activity in older adults: A systematic review of qualitative studies. Int. J. Behav. Nutr. Phys. Act. 11, 79. https://doi.org/10.1186/1479-5868-11-79.

Morita, A., Takano, T., Nakamura, K., Kizuki, M., Seino, K., 2010. Contribution of interaction with family, friends and neighbours, and sense of neighbourhood attachment to survival in senior citizens: 5-year follow-up study. Soc Sci Med 70 (4), 543–559. https://doi.org/10.1016/j.socscimed.2009.10.057.

Oladipo, T. Boko Haram crisis: Maiduguri under siege in Nigeria. *Africa News, British Broadcasting Corporation. May 11, 2013*. http://www.bbc.com/news/av/world-africa-22491094/boko-haram-crisis-maiduguri-under-siege-in-nigeria. Accessed March 7, 2023.

Omotara, B., Yahya, S., Wudiri, Z., Amodu, M., Bimba, J., Unyime, J., 2015. Assessment of the Determinants of Healthy Ageing among the Rural Elderly of North-Eastern Nigeria. Health 7, 754–764. https://doi.org/10.4236/health.2015.76090.

Oyeyemi, A.L., Kasoma, S.S., Onywera, V.O., Assah, F., Adedoyin, R.A., Conway, T.L., Moss, S.J., Ocansey, R., Kolbe-Alexander, T.L., Akinroye, K.K., Prista, A., Larouche, R., Gavand, K.A., Cain, K.L., Lambert, E.V., Aryeetey, R., Bartels, C., Tremblay, M.S., Sallis, J.F., 2016. NEWS for Africa: Adaptation and reliability of a built environment questionnaire for physical activity in seven African countries. Int. J. Behav. Nutr. Phys. Act. 13 (1) https://doi.org/10.1186/s12966-016-0357-y.

Oyeyemi, A.L., Conway, T.L., Adedoyin, R.A., et al., 2017. Construct validity of the neighbourhood environment walkability scale for Africa. Med. Sci. Sports Exerc. 49 (3), 482–491. https://doi.org/10.1249/MSS.0000000000001131.

Oyeyemi, A.L., Kolo, S.M., Oyeyemi, A.Y., Omotara, B.A., 2019. Neighborhood environmental factors are related to health-enhancing physical activity and walking among community dwelling older adults in Nigeria. Physiother. Theory Pract. 35 (3), 288–297. https://doi.org/10.1080/09593985.2018.1443187.

Oyeyemi, A.L., Adegoke, B.O., Sallis, J.F., Oyeyemi, A.Y., de Bourdeaudhuij, I., 2012. Perceived crime and traffic safety is related to physical activity among adults in Nigeria. BMC Public Health 12, 294. https://doi.org/10.1186/1471-2458-12-294.

Parra, D.C., Gomez, L.F., Sarmiento, O.L., et al., 2010. Perceived and objective neighbourhood environment attributes and health related quality of life among the elderly in Bogotá. Colombia. Soc Sci Med 70, 1070–1106. https://doi.org/10.1016/j.socscimed.2009.12.024.

Oyeyemi, A.L., Bello, U.M., Philemon, S.T., Aliyu, H.N., Majidadi, R.W., Oyeyemi, A.Y, 2014. Examining the reliability and validity of a modified version of the International Physical Activity Questionnaire, long form (IPAQ-LF) in Nigeria: A cross-sectional study. BMJ Open 4, e005820. https://doi.org/10.1136/bmjopen-2014-005820.

Raggi A, Corso B, Minicuci N, et al. Determinants of quality of life in ageing populations: Results from a cross-sectional study in Finland, Poland and Spain. PLoS ONE. 2016.; 11(7):e0159293.

Richard, L., Gauvin, L., Gosselin, C., Laforest, S., 2008. Staying connected: Neighbourhood correlates of social participation among older adults living in an urban environment in Montreal. Quebec. Health Promot Int. 24, 46–57. https://doi.org/10.1093/heapro/dan039.

Roswall, N., Høgh, V., Envold-Bidstrup, P., et al., 2015. Residential exposure to traffic noise and health-related quality of life—a population-based study. PLoS ONE 10, e0120199. https://doi.org/10.1371/journal.pone.0120199.

Rzewnicki, R., Auweele, Y.V., Bourdeaudhuij, I.D., 2003. Addressing over-reporting on the international physical activity questionnaire (IPAQ) telephone survey with a population sample. Public Health Nutr 6 (3), 299–305. https://doi.org/10.1079/PHN2002427.

Sallis, J.F., Spoon, C., Cavill, N., Engelberg, J.K., Gebel, K., Parker, M., Thornton, C.M., Lou, D., Wilson, A.L., Cutter, C.L., Ding, D., 2015. Co-benefits of designing communities for active living: An exploration of literature. Int. J. Behav. Nutr. Phys. Act. 12 (1) https://doi.org/10.1186/s12966-015-0188-2.

Salvo, D., Garcia, L., Reis, R.S., Stankov, I., Goel, R., Schipperijn, J., Hallal, P.C., Ding, D., Pratt, M., 2021. Physical Activity Promotion and the United Nations Sustainable Development Goals: Building Synergies to Maximize Impact. J. Phys. Act. Health 18 (10), 1163–1180. https://doi.org/10.1123/jpah.2021-0413.

Sugiyama T, Leslie E, Giles-Corti B, Owen N. Associations of neighbourhood greenness with physical and mental health: Do walking, social coherence and local social interaction explain the relationships? J Epidemiol Community Health. 2008;62:e9. doi:10.1136/jech.2007.064287.

Sugiyama, T., Thompson, C.W., 2007. Outdoor environments, activity and the well-being of older people: Conceptualising environmental support. Environ Plan A 39 (8), 1943–1960. https://doi.org/10.1068/a38226.

Sugiyama, T., Thompson, C.W., Alves, S., 2009. Associations between neighborhood open space attributes and quality of life for older people in Britain. Environ. Behav. 41 (1), 3–21. https://doi.org/10.1177/0013916507311688.

Takano, T., Nakamura, K., Watanabe, M., 2002. Urban residential environments and senior citizens' longevity in megacity areas: the importance of walkable green spaces. J. Epidemiol. Community Health 56 (12), 913–998. https://doi.org/10.1136/jech.56.12.913.

Twisk, J.W.R., 2006. Applied Multilevel Analysis. Cambridge University Press, Cambridge, UK.

United Nations, Department of Economic and Social Affairs, Population Division. *World Population Prospects 2022: Summary of Results*. UN DESA/POP/2022/TR/NO. 3. United Nations, New York, 2022. https://www.un.org/development/desa/pd/sites/www.un.org.development.desa.pd/files/wpp2022_summary_of_results.pdf Accessed February, 2023.

Van Cauwenberg, J., Clarys, P., De Bourdeaudhuij, I., Van Holle, V., Verté, D., De Witte, N., De Donder, L., Buffel, T., Dury, S., Deforche, B., 2013. Older adults' transportation walking: a cross-sectional study on the cumulative influence of physical environmental factors. Int. J. Health Geogr. 12 (1), 37. https://doi.org/10.1186/1476-072X-12-37.

White, D.K., Jette, A.M., Felson, D.T., Lavalley, M.P., Lewis, C.E., Torner, J.C., Nevitt, M. C., Keysor, J.J., 2010. Are features of the neighborhood environment associated with disability in older adults? Disabil. Rehabil. 32 (8), 639–645. https://doi.org/10.3109/09638280903254547.

World Health Organization Quality of Life Group. Development of the World Health Organization WHOQOLBREF quality of life assessment. Psychological Medicine. 1998;*28*:551–58.

World Health Organization. *Global age-friendly cities: a guide*. Geneva, Switzerland: WHO; 2007. https://www.who.int/publications/i/item/9789241547307 Accessed March, 2023.

World Health Organization.. *World report on ageing and health*. Geneva, Switzerland: WHO; 2015.

World Health Organization. *Guidelines on physical activity and sedentary behaviour*. Geneva, Switzerland: WHO; 2020.