Research Article

Could geographical features of green spaces influence physical exercise? Examining the roles of neighbourhood diversity and single status

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Background: A rapidly growing body of research suggests that exposure to green space has been associated with better physical and mental health. This study aimed to examine whether the neighbourhood diversity and single status simultaneously mediated associations between geographical features of green spaces and green physical exercise.

Methods: Data were from a sample of 1387 full-time employees from the green exercise. Using hierarchical regressions, logistic regressions, and linear regressions with multiple fixed effects, this study investigate the associations of geographical features of green spaces with transport modes, travel duration to green space, and visiting and exercise time, respectively.

Results: The sample was dominated by middle-aged, British nationality, male, and employees walking to green space. Neighbourhood diversity and single status moderated the association with daily visit. Neighbourhood diversity moderated the associations with choices of car, bus, and walk, hours visiting LGS, and vigorous exercise time, respectively. Likewise, single status moderated the associations with vigorous exercise time.

Conclusion: This population-based study underscores the importance of neighbourhood diversity and single status in the transport modes and vigorous exercise time. These findings indicate that the residential environment and marital status could influence the choices of transport modes and vigorous exercise time. Additional research is needed to determine how work time can influence level and time of green physical exercise.

 doi.org/10.32388/HZNCLH

Introduction

Two meta-analyses showed persons with nature connectedness were significantly happier[1] and healthier[2] than those without. Urban nature connectedness was positively predicted by engagement in outdoor activities and increased hours per week spent in nature [3]. Contact with nature may decrease mental health symptoms [4] and protect for psychological well-being [5]. A survey-based study showed that nature-based activities had a positive effect on alleviating state anxiety levels [6]. Especially, regular contact with nature may improve protect individual mental and emotional health [7]. Regarding the underlying cognitive mechanisms, color green has a contributory effect toward positive green exercise outcomes [8].

Green spaces provide ecosystem services that are vital to public health [9]. For example, a meta-narrative evidence synthesis indicated that urban green space has an important role in a culture of health and well-being [10]. In addition, a study indicates that all kinds of green spaces could decrease maternal mortality [11]. Physiologically, access and exposure to green space might be critical to prevention of mental health [12]; [13]; [14]; [15]; [16]. A study showed exposure to urban green spaces were associated with mental health [17]. Green spaces increase physical activity [18] and positively influenced the longevity of older adults [19].

Two studies identified physical activity time was a significant risk factor of hypertension incidence [20] and cognitive change symptoms [21]. Overall, appropriate intensity of physical activity was associated with lower anxiety and depression risk outcomes [22]. Furthermore, physical inactivity was associated with elevated levels of 4 proteins [23] and the growing incidence of cardiovascular disease [24].

A systematic review showed green exercise offers superior benefits with exposure to nature [25]. An investigation indicated enjoyment was the greatest intrinsic motivator for adherence to green exercise [26]. Green exercise can facilitating well-being [27], reduce chronic pain [28], improve acute psychological well-being [29], improved self-esteem [30], relieve acute psychological stress [31]. Green exercise at the workplace could be a profitable way to manage stress and induce restoration among employees [32].

It reported growing incidence of physical inactivity [33] and physical activity time in various employment status [34] in the Western world. The aims of this study were to assess the associations of geographical features of green spaces with green physical activity among the employed individuals

doi.org/10.32388/HZNCLH

with a publicly available survey data. Considering fixed effects of socio-demographic factors, a series of linear and instrumental-variable regressions were designed to provide evidences for the associations of interest. The empirical findings from statistical analyses would provide insights for physical activity in green spaces for employed individuals.

Literature review

Multiple studies confirmed the associations between amounts [35], area-level characteristics [36], density [37], and ratio [38] of green spaces and cardiovascular health. Several studies found proximity to green spaces was beneficial to several cardiovascular outcomes in urban spaces ([39]; [40]). But, utilization of green spaces was related to the good health-related variables [41]. Also, the green spaces for exercise were confirmed to be beneficial for cardiovascular health in the older population in China [42]. Area percentage of green spaces was confirmed to reduce the morbidity of diseases [43]. In addition, strolls and park visits were found to provide positive emotions to working mothers [44]. Consistent with literature, this study therefore hypothesized that:

Hypothesis 1: There are difference between visiting and physical exercise time regarding geographical features of green spaces.

Daily exercise is likely to be associated with better workers' health and work performance [45]. Several Systematic review and meta-analyses indicated regular exercise increases muscle strength [46] and had a specific anti-inflammatory effect on blood [47]. Some current studies reported that regular exercise improves asthma control [48], protects against the aging-associated decline [49], and reduced risk of osteoporosis in postmenopausal women[50]. Consistent with literature, this study therefore hypothesized that:

Hypothesis 2: Geographical features of green spaces have the associations with daily visit.

Distance to green spaces determines the choice of transport modes. Transport can accounts for part of physical activity[51]. Walking and bicycle use were associated with good self-perceived health [52] . Cycling has been shown to be associated to lower body mass index [53]. City bus is a safe mode[54] and make transportation universally accessible [55].Long time spent in transport modes lead to negative health outcomes, including fatigue-related elevated risk of anxiety or mood disorders[56], cardio-metabolic risk [57], depressive symptoms[58],weight gain[59], overweight and abdominal obesity[60]. Persons intended to physical activity would to avoid the potential deleterious health

doi.org/10.32388/HZNCLH

effects caused by prolonged traveling time and choose appropriate transport modes. Accordingly, this study hypothesized that:

Hypothesis 3: Geographical features of green spaces have the associations with transport modes.

Green exercise among adult Norwegians, the socio-economic inequities relative to the perceived accessibility to nature were reported [61]. In an early study, the presence of partners moderated the relationship between engagement with nature and physical activity [62]. Consistent with literature, this study therefore hypothesized that:

Hypothesis 4: Marital status moderated the associations of geographical features of green spaces with green physical activity time.

Likewise, the detrimental health effect of living in disadvantaged neighbourhoods was observed [63]. Meanwhile, the perceived walkability of lower income neighbourhoods is worse in comparison with higher income neighbourhoods in South African adolescents [64]. Perceptions of neighbourhood environment did not consistently predict physical activity in a deprived and ethnically diverse urban population[65]. Accordingly, this study hypothesized that:

Hypothesis 5: Neighbourhood diversity moderated the associations of geographical features of green spaces with green physical activity time.

In this study, a series of linear and instrumental-variable regressions with many levels of fixed effects models were designed to provide evidences for the associations above. The empirical findings from statistical analyses would provide insights for physical activity in green spaces for full-time employees.

Method

Ethics approval and consent to participate

The data adopted was from a publicly available survey dataset whose ethical approval was obtained from the institutional review board at University of Essex, UK. Pseudonyms are used at all times to maintain confidentiality. Informed consent was obtained from all research participants.Written informed consent was obtained from all participants before they agreed to participate in the study. Participants were informed that they could leave the study at any time without penalty, and all personal information was kept confidential. Thus, it was not necessary to obtain ethical approval from the institutional review board at the author's institution.

Data source

The data used in the present study were extrapolated from a publicly available online survey [66]. From 25 September 2011 to10 October 2011, the data were collected by on-line survey in English language via Harris Interactive in the United Kingdom. This data consists of a sample of 1387 full time employed individuals (22-65 year old). The study has been designed to investigate the influence of social and physical environment in the workplace on health, well-being and behaviour. Information in the questionnaire included demographic information, living location and conditions, neighbourhood and socialization, physical activity, other activities, commuting, visits and engagement with green space, green exercise and barriers to visiting green space. In the questionnaire, green space includes public parks, public gardens, public wooded area, common ground, public recreational space, local off-road footpaths or cycle ways. Vigorous exercises include activities such as heavy lifting, digging, aerobics, running or fast cycling. Moderate exercises include activities such as cycling, and light games.

Main variables

Socio-demographic factors

Socio-demographic factors were age (continuous, unit: year, ranging from 22 to 65 years), gender (female=0, male=1), nationality, marital status, education level, household income, neighbourhood diversity, and self-reported health.

British nationality

In the sample, the distribution of nationality was British (87.31%), Irish (1.51%), any other white background (5.34%), white and black Caribbean (0.07%), white and black African (0.22%), white and Asian (0.36%), any other mixed background (0.43%), Indian (1.87%), Pakistani (0.50%), Bangladeshi (0.14%), any other Asian background (0.29%), Caribbean (0.22%), African (0.65%), any other black background (0.07%), Chinese (0.43%), and any other ethnic origin (0.58%).

Marital status

In the sample, the distribution of marital status was never married (25.38%), married or civil union (48.09%), divorced (5.62%), separated (1.80%), widow/widower (0.94%), living with partner (17.66%), decline to answer (0.50%). The observations with decline to answer are deleted. Thus, single status can be defined with the response options of no (0= never married/ divorced/ separated/ widow/widower) and yes (1= married or civil union/ living with partner).

Education level

Education was assessed by the question: "Which of the following, if any, is the highest educational or professional qualification you have obtained?" The response options were GCSE/O-Level/CSE (14.49%), vocational qualifications (11.10%), A-Level/Scottish higher or equivalent (18.67%), bachelor degree or equivalent (35.26%), masters/PhD or equivalent (16.29%), no formal qualifications (1.37%), other (2.09%), still studying (0.72%). For statistical convenience, the variable was renamed as academic degree and recoded into no (GCSE/O-Level/CSE, vocational qualifications, A-Level/Scottish higher or equivalent, no formal qualifications, other, still studying) and yes (bachelor degree or equivalent and masters/PhD or equivalent).

Household income

Income was assessed by the question: "Which of the following income categories best describes your total 2010 household income before taxes?" The response options were less than £10,000 (1.08%), £10,000 to £14,999 (3.46%), £15,000 to £19,999 (7.28%), £20,000 to £24,999 (9.23%), £25,000 to £29,999 (9.16%), £30,000 to £39,999 (19.39%), £40,000 to £49,999 (12.69%), £50,000 to £74,999 (17.59%), £75,000 to £99,999 (6.06%), £100,000 to £149,999 (1.80%), £150,000 or more (1.30%), prefer not to say(10.96%). The observations with "prefer not to say" are deleted. Here, low income was defined with the response options with no (=0, £40,000 or more) and yes (=1, less than and equal to £39,999).

Neighbourhood diversity

Neighbourhood diversity was assessed by the question of "How diverse is your neighbourhood?" with the response options of not at all diverse (13.12%), not very diverse (32.44%), somewhat diverse (35.04%), very diverse (13.34%), and extremely diverse (6.06%). For statistical convenience, the variable was recoded into no (0=not at all diverse/ not very diverse) and yes (1= somewhat diverse/ very diverse/ extremely diverse).

doi.org/10.32388/HZNCLH

Poor self-reported health

Self-reported health was assessed with a single item which asked "Overall, how would you rate your health in the past month?" The response options were terrible (0.94%), very poor (2.02%), poor (8.51%), fair (27.33%), good (33.24%), very good (21.27%), and excellent (6.71%). Thus, poor self-reported health can be defined with the response options of no (0=fair/good/very good/excellent) and yes (1=terrible/very poor/poor).

Geographical features of green spaces

Characteristics of green space included perceived quality, perceived accessibility, percentage of local accessible green spaces available near work (LGS %), and number of barriers to green space. Perceived accessibility to green space was assessed by asking participants "How easy is it to get to the green space local to your work?" Participants responded from 1 = "very difficult" to 7 = "very easy". The observations with "Don't know" are deleted. Among the available 1,365 observations, the response options were distributed by very difficult (0.44%), difficult (0.81%), somewhat difficult (2.05%), neither easy nor difficult (7.40%), somewhat easy (14.29%), easy (23.30%), and very easy (51.72%). For statistical convenience, perceived accessibility quality was recoded as difficult access (0=very difficult/difficult/somewhat difficult/neither easy nor difficult) and easy access(1=somewhat easy/easy/very easy).

Perceived quality was assessed with a single item that asked "Considering number, size and quality, how would you rate the quality of your local accessible green spaces that are close to your work?" Participants responded from 1 = "Terrible" to 7 = "Excellent". The observations with "Don't know" are excluded. Among the available 1,366 observations, the response options were distributed by terrible (0.51%), very poor (1.10%), poor (4.32%), fair (19.11%), good (27.23%),very good (26.43%), and excellent (21.30%). For statistical convenience, perceived quality was recoded as low quality (0=more than and equal to 15 minutes) and high quality (1=less than and equal to 10 minutes).

Barriers to green space included lack of time, distance, size, quality, access, undesirable people, lack of other people, safety, dogs , own health, lack of motivation, tiredness, don't wish to, and too many people. Thus, number of barriers to green space was obtained by sum of all the barriers to green space.

Travel duration

Travel duration to green space was assessed by the question of "How long does it take you to get to the green space local to your work?" Among the available 1331 observations, the distribution of response options were 0-5 minutes (47.18%), 5-10 minutes (35.01%),15-20 minutes (14.05%), 20-25 minutes (2.33%), 25-30 minutes (0.98%), and more than 30 minutes (0.45%). For statistical convenience, travel duration was recoded as 0 (more than and equal to 15 minutes) and 1 (less than and equal to 10 minutes).

Outcome variables

Daily visit

Visit frequency to green space was assessed by asking participants "How often do you visit the green space closest to your work?" The response options were every day (10.31%), few times a week (18.75%), once a week (15.14%), few times a month (20.62%), once a month (8.22%), rarely (22.93%), and never visit my local green space or any (4.04%). Thus, daily visit was obtained with the response options with no (0=few times a week, once a week, few times a month, once a month, rarely, never visit my local green space or any) and yes (=1).

Visiting and exercise time

Hours visiting local and non-local green spaces was reflected by the question: "Thinking of last week, how many hours on average do you engage in each of these activities per week?" The answers were hours visiting local and non-local green spaces, respectively. Physical exercise time included vigorous exercise time and non-vigorous exercise time. The former was reflected by the question: "Thinking of last week, how much time per day (on average) did you spend doing vigorous exercise?" The latter was reflected by the question: "Thinking of last week, how much time per day (on average) did you spend doing non-vigorous exercise?" The responses were continuous variables with unit of hour.

Statistical analyses

We first examined daily visit differences in socioeconomic factors, geographical features of green spaces, transport modes, and visiting and exercise time using the Chi-square test. Then, hierarchical regression was conducted to examine whether neighbourhood diversity and single status moderated the association of geographical features of green spaces (perceived quality, perceived accessibility, LGS %, number of barriers to green space, and travel duration) with daily visit. Logistic regressions were conducted to examine whether neighbourhood diversity and single status moderated the associations of geographical features of green spaces (perceived quality, perceived accessibility, LGS %, number of barriers to green space, and travel duration) with transport modes. With fixed effects of socioeconomic factors, linear regressions with multiple fixed effects were conducted to examine whether neighbourhood diversity and single status moderated the associations of geographical features of green spaces (perceived quality, perceived accessibility, LGS %, number of barriers to green space, and travel duration) with visiting and exercise time. Statistical analysis was performed using Stata SE17 (Stata Corp LLC).

Result

Sample characteristics

Participants' (n = 1387) average age was 41.36 years (SD, 10.87) ranging from 22 to 65 years, 57.10% were male and 87.31% were of British nationality. Among the available 1,331 employed persons, 26.30% travel to green space by car, 4.88% travel to green space by bus, 2.03% travel to green space by train, 9.54% travel to green space by cycle, 86.55% walk to green space, and 1.28% other - travel to green space by.There are significant differences between the employees with and without daily visit regarding single status, low income, car mode, perceived quality, perceived accessibility, travel duration, age, hours visiting local green spaces, hours visiting non-local green spaces, LGS %,vigorous exercise time, and non-vigorous exercise time.

	Daily visit		chi2	P
	No (%)	Yes (%)		
Gender ((n=1387)			0.6898	0.406
No	38.14	4.76		
Yes	51.55	5.55		
Single status ((n=1380)			5.4351	0.020**
No	58.33	7.75		
Yes	31.30	2.61		
British nationality ((n=1387)			0.5734	0.449
No	11.18	1.51		
Yes	78.51	8.80		
Academic degree ((n=1387)			0.3365	0.562
No	43.69	4.76		
Yes	46.00	5.55		
Low income ((n=1387)			6.0547	0.014**
No	44.20	6.20		
Yes	45.49	4.11		
Neighbour diversity ((n=1387)			1.4710	0.225
No	40.37	5.19		
Yes	49.32	5.12		
Poor SRH ((n=1387)			0.4399	0.507
No	79.24	9.30		
Yes	10.45	1.01		
Car mode ((n=1331)			3.7281	0.054*
No	65.06	8.64		
Yes	24.19	2.10		

	Daily visit		chi2	P
Bus mode ((n=1331)			0.0000	0.995
No	84.90	10.22		
Yes	4.36	0.53		
Train mode ((n=1331)			1.7371	0.188
No	87.60	10.37		
Yes	1.65	0.38		
Cycle mode((n=1331)			1.0220	0.312
No	80.99	9.47		
Yes	8.26	1.28		
Walk mode((n=1331)			2.6137	0.106
No	12.47	0.98		
Yes	76.78	9.77		
Other ((n=1331)			0.8557	0.355
No	88.20	10.52		
Yes	1.05	0.23		
Perceived quality ((n=1366)			19.7820	0.000***
No	24.01	1.02		
Yes	65.52	9.44		
Perceived accessibility ((n=1365)			8.6678	0.003***
No	10.33	0.37		
Yes	79.19	10.11		
Travel duration ((n=1331)			16.3247	0.000***
No	17.21	0.60		
Yes	72.05	10.14		
	Mean(se)	Mean(se)	Difference	P

doi.org/10.32388/HZNCLH

	Daily visit		chi2	P
Age	40.954(0.303)	44.916(0.980)	-3.962(0.954)	0.000***
Hours visiting local green spaces	1.642(0.073)	5.371(0.396)	-3.728(0.254)	0.000***
Hours visiting non-local green spaces	1.158(0.064)	2.035(0.450)	-0.877(0.242)	0.000***
Local Green Space %	49.323(0.751)	60.620(2.431)	-11.297(2.348)	0.000***
Vigorous exercise time	7.947(0.088)	9.280(0.297)	-1.333(0.274)	0.000***
Non-vigorous exercise time	8.936(0.059)	9.874(0.189)	-0.938(0.182)	0.000***
N	1244	143		

Table 1. Sample characteristics.

** p<0.1,** p<0.05, *** p<0.01*

Relationships between visiting and exercise time

The relationships of hours visiting local green spaces with vigorous and non-vigorous exercise time at green space can be seen in figures 1 and 2. Basically, long hours visiting local green spaces possibly lead to long vigorous and non-vigorous exercise time at green space. There are significant differences between the persons with and without daily visit regarding the relationships of interest.

The relationships of hours visiting non-local green space with vigorous and non-vigorous exercise time at green space can be seen in figures 3 and 4. Basically, long hours visiting non-local green space possibly lead to long vigorous and non-vigorous exercise time at green space. There are significant differences between the employees with and without daily visit regarding the relationships of interest. Thus, Hypothesis 1 was supported.

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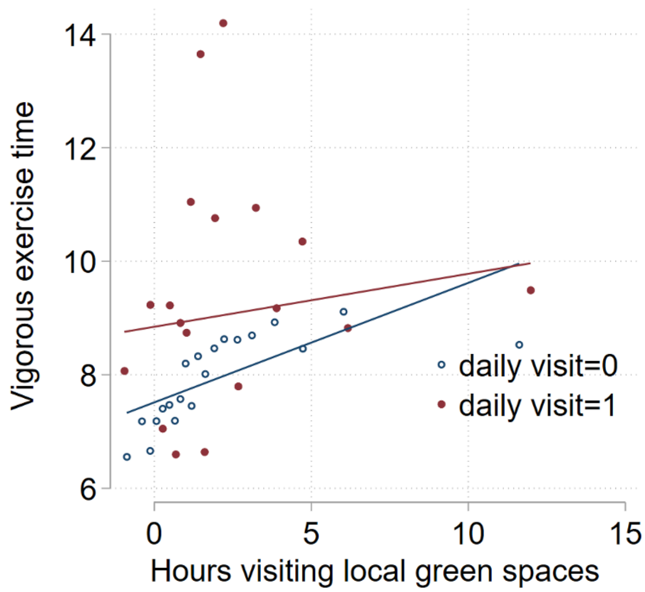

Figure 1. Vigorous exercise time.

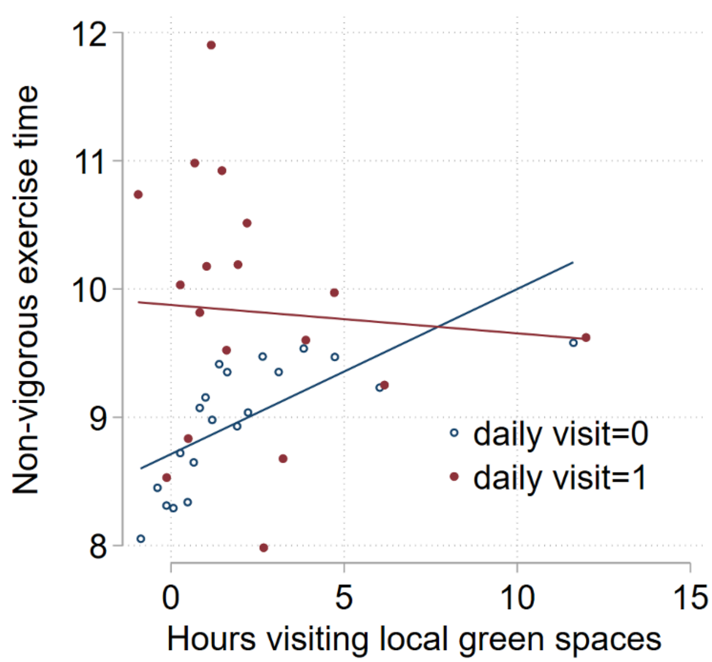

Figure 2.Non-vigorous exercise time.

doi.org/10.32388/HZNCLH

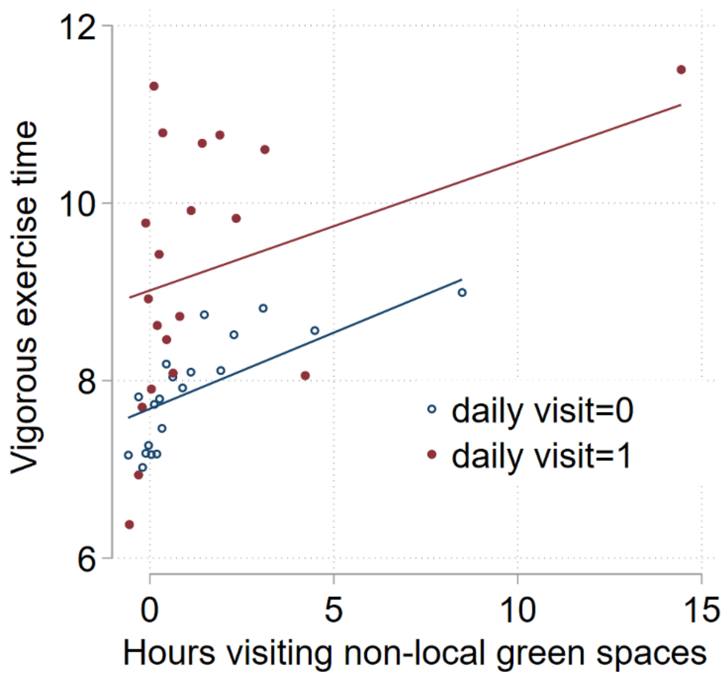

Figure 3. Vigorous exercise time.

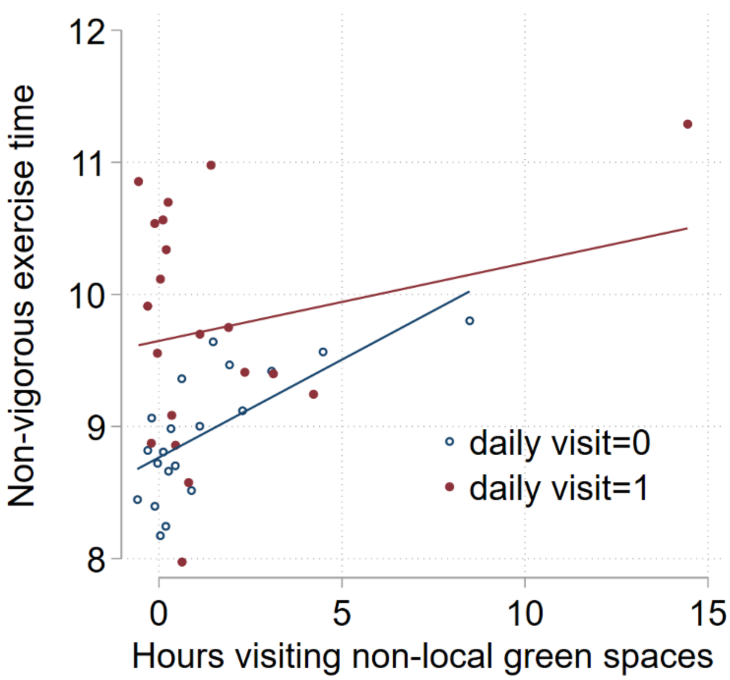

Figure 4.Non-vigorous exercise time.

doi.org/10.32388/HZNCLH

Associations with daily visit

Age, perceived quality, LGS %, barriers, travel duration, perceived quality×neighbourhood diversity, and perceived accessibility×single status were identified significant factors associated with daily visit. Here, barriers were the strongest factor associated with daily visit, followed by perceived quality×neighbourhood diversity, single status, perceived accessibility×single status, perceived quality, LGS %, age, and travel duration. Neighbourhood diversity moderated the association of perceived quality with daily visit. Single status moderated the association of perceived accessibility with daily visit. Thus, Hypothesis 2 was supported.

	Model 1	Model 2	Model 3	Model 4
Age	0.118*** (0.001)	0.088*** (0.001)	0.086*** (0.001)	0.085*** (0.001)
Gender	-0.023 (0.018)	-0.030 (0.018)	-0.029(0.018)	-0.034(0.018)
Single status	-0.034 (0.018)	-0.028 (0.018)	-0.025 (0.018)	-0.137*(0.054)
British nationality	-0.032 (0.028)	-0.050* (0.028)	-0.050*(0.028)	-0.047 (0.029)
Academic degree	0.030 (0.019)	0.035 (0.019)	0.038(0.019)	0.038(0.019)
Low income	-0.051* (0.019)	-0.027 (0.018)	-0.024(0.019)	-0.023(0.019)
Neighbour diversity	-0.007 (0.018)	0.031 (0.019)	-0.013(0.064)	-0.003(0.064)
Poor SRH	-0.009 (0.028)	0.015 (0.028)	0.015(0.028)	0.012 (0.027)
Perceived quality		0.048* (0.019)	0.119***(0.025)	0.121***(0.031)
Perceived accessibility		0.010 (0.025)	-0.028 (0.043)	-0.060(0.052)
LGS %		0.093*** (0.000)	0.076* (0.001)	0.095* (0.001)
Barriers		-0.119*** (0.006)	-0.158*** (0.010)	-0.186*** (0.011)
Travel duration		0.062*** (0.018)	0.068 ** {0.026)	0.065* (0.030)
Perceived quality×neighbourhood diversity			-0.151 *** {0.036)	-0.158*** (0.037)
Perceived accessibility×neighbourhood diversity			0.109(0.051)	0.096(0.052)
LGS %×neighbourhood diversity			0.033 (0.001)	0.038(0.001)

	Model 1	Model 2	Model 3	Model 4
Barriers×neighbourhood diversity			0.062 (0.013)	0.061 (0.013)
Travel duration×neighbourhood diversity			-0.005(0.035)	-0.001 (0.036)
Perceived quality×single status				-0.003(0.038)
Perceived accessibility×single status				0.129** (0.045)
LGS %×single status				-0.060 (0.001)
Barriers×single status				0.062 (0.013)
Travel duration×single status				0.003(0.035)
R-squared	0.021	0.057	0.062	0.066
R2 change		0.037	0.005	0.004

Table 2. Hierarchical regression on daily visit. (N=1270)

*Standard errors in parentheses. * p<0.1,** p<0.05, *** p<0.01.*

Associations with transport modes

In Table 3, perceived accessibility, barriers, and LGS %×neighbourhood diversity is identified significant factor positively associated with choice of car. Age, perceived quality, perceived accessibility, and perceived accessibility×neighbourhood diversity is identified significant factor positively associated with choice of bus. Age, gender, single status, British nationality, and perceived accessibility is identified significant factor positively associated with choice of train. Age, gender, academic degree, and diversity is identified significant factor positively associated with choice of cycle. Academic degree, perceived accessibility,travel duration, and LGS %×neighbourhood diversity is identified significant factor positively associated with choice of walk.Thus, Hypothesis 3 was supported.

doi.org/10.32388/HZNCLH

	Car	Bus	Train	Cycle	Walk
Age	1.001(0.989-1.012)	0.962***(0.936-0.988)	0.907***(0.859-0.957)	0.978**(0.961-0.995)	1.009(0.994-1.025)
Gender	1.024(0.788-1.329)	1.061(0.611-1.843)	11.705***(2.672-51.280)	1.575**(1.054-2.353)	1.121(0.788-1.596)
Single status	0.590(0.210-1.657)	1.964(0.313-12.318)	25.418**(1.577-409.766)	0.229(0.039-1.330)	0.795(0.237-2.668)
British nationality	1.023(0.696-1.504)	0.693(0.351-1.369)	0.349**(0.126-0.966)	0.794(0.468-1.345)	0.743(0.431-1.281)
Academic degree	0.984(0.752-1.288)	0.825(0.466-1.462)	0.560(0.210-1.489)	1.580**(1.047-2.384)	1.469**(1.020-2.114)
Low income	0.883(0.672-1.159)	1.088(0.614-1.930)	0.837(0.329-2.131)	0.721(0.479-1.086)	0.883(0.613-1.272)
diversity	0.508(0.205-1.260)	0.539(0.097-3.011)	0.147(0.011-2.016)	0.259*(0.066-1.024)	2.081(0.694-6.235)
Poor SRH	0.999(0.661-1.510)	0.906(0.362-2.266)	0.692(0.137-3.483)	0.600(0.281-1.281)	0.749(0.446-1.259)
Perceived quality	0.958(0.557-1.647)	4.987*(0.774-32.123)	12.382(0.508-301.949)	0.864(0.372-2.003)	1.367(0.681-2.745)
Perceived accessibility	0.468**(0.226-0.966)	0.180*(0.027-1.209)	0.079*(0.004-1.606)	0.445(0.144-1.378)	2.440**(1.043-5.704)
LGS %	0.995(0.988-1.003)	0.981(0.960-1.004)	0.970(0.927-1.016)	0.998(0.986-1.009)	1.005(0.995-1.016)
Barriers	1.202***(1.052-1.374)	0.958(0.642-1.430)	1.184(0.677-2.071)	0.834(0.668-1.041)	0.907(0.760-1.082)

	Car	Bus	Train	Cycle	Walk
Travel duration	0.802(0.442-1.454)	0.404(0.092-1.764)	0.547(0.048-6.297)	0.804(0.302-2.144)	1.881*(0.911-3.882)
Perceived quality×neighbourhood diversity	1.354(0.690-2.658)	0.370(0.056-2.440)	0.376(0.012-11.422)	1.292(0.457-3.651)	0.507(0.213-1.206)
Perceived accessibility×neighbourhood diversity	1.331(0.545-3.253)	10.212** (1.365-76.381)	6.990(0.246-198.686)	2.364(0.576-9.703)	0.797(0.284-2.236)
LGS %×neighbourhood diversity	1.011**(1.001-1.022)	1.003(0.979-1.028)	1.035(0.983-1.089)	1.007(0.993-1.022)	0.986** (0.973-1.000)
Barriers×neighbourhood diversity	0.893(0.749-1.064)	1.235(0.796-1.917)	1.229(0.652-2.318)	1.174(0.889-1.549)	1.097(0.873-1.380)
Travel duration×neighbourhood diversity	0.594(0.291-1.215)	0.631(0.134-2.982)	0.761(0.060-9.734)	0.680(0.216-2.138)	1.998(0.836-4.774)
Perceived quality×single status	0.875(0.436-1.758)	0.485(0.115-2.040)	0.382(0.022-6.487)	1.407(0.465-4.261)	1.600(0.657-3.897)
Perceived accessibility×single status	1.007(0.398-2.547)	0.712(0.133-3.812)	0.531(0.032-8.805)	1.538(0.309-7.653)	2.285(0.803-6.502)
LGS %×single status	1.004(0.993-1.014)	1.017(0.994-1.041)	0.973(0.922-1.026)	1.001(0.986-1.017)	0.995(0.981-1.009)
Barriers×single status	1.086(0.896-1.315)	0.869(0.602-1.254)	0.838(0.445-1.578)	0.990(0.729-1.345)	1.027(0.799-1.318)
Travel duration×single status	1.320(0.645-2.701)	0.742(0.226-2.433)	0.289(0.038-2.169)	2.560(0.776-8.449)	0.517(0.215-1.244)

Table 3. Logistic regression on transport modes (N=1270).

*95% confidence interval in parentheses. * p<0.1,** p<0.05, *** p<0.01.*

Associations with visiting and exercise time

Barriers×neighbourhood diversity was identified significant factors positively associated with hours visiting LGS. No factors speculated were identified significant factors positively associated with hours visiting non-LGS. Perceived quality×neighbourhood diversity, LGS %×neighbourhood diversity, travel duration×neighbourhood diversity, perceived accessibility×single status were identified significant factors positively associated with vigorous exercise time. Perceived accessibility×neighbourhood diversity, barriers×neighbourhood diversity, perceived quality×single status were identified significant factors positively associated with non-vigorous exercise time.

Neighbourhood diversity moderated the associations of barriers with hours visiting LGS. Neighbourhood diversity moderated the associations of perceived quality, LGS %, travel duration, and perceived accessibility with vigorous exercise time. Single status moderated the associations of perceived accessibility with vigorous exercise time. Neighbourhood diversity moderated the associations of perceived accessibility with vigorous exercise time. Single status moderated the associations of perceived quality with vigorous exercise time. Thus, Hypotheses 4 and 5 were supported.

	Hours visiting LGS	Hours visiting non-LGS	Vigorous exercise time	Non-vigorous exercise time
Perceived quality×neighbourhood diversity	0.467(0.358)	0.266(0.322)	1.218***(0.331)	0.321(0.241)
Perceived accessibility×neighbourhood diversity	-0.015(0.424)	0.097(0.381)	-0.136(0.392)	0.533*(0.285)
LGS %×neighbourhood diversity	-0.002(0.005)	-0.002(0.005)	0.013***(0.005)	-0.004(0.003)
Barriers×neighbourhood diversity	-0.242*** (0.085)	-0.005(0.076)	0.031(0.079)	0.012(0.057)
Travel duration×neighbourhood diversity	0.069(0.354)	-0.150(0.318)	-1.268*** (0.328)	-0.344(0.238)
Perceived quality×single status	0.611(0.420)	0.050(0.378)	0.110(0.389)	0.621** (0.283)
Perceived accessibility×single status	-0.547(0.551)	0.031(0.496)	-0.895*(0.511)	-0.531 (0.371)
LGS %×single status	0.007(0.006)	-0.002(0.005)	0.001(0.006)	0.003(0.004)
Barriers×single status	-0.159(0.113)	0.076(0.102)	-0.146(0.105)	0.067(0.076)
Travel duration×single status	0.021(0.464)	-0.244(0.418)	0.625(0.430)	-0.313(0.312)
Fixed effect				
Age	Yes	Yes	Yes	Yes
Gender	Yes	Yes	Yes	Yes
British nationality	Yes	Yes	Yes	Yes
Academic degree	Yes	Yes	Yes	Yes
Low income	Yes	Yes	Yes	Yes
Poor SRH	Yes	Yes	Yes	Yes
R-squared	0.0766	0.0368	0.1897	0.0686
Adj R-squared	0.0324	-0.0093	0.1509	0.0240

doi.org/10.32388/HZNCLH

	Hours visiting LGS	Hours visiting non-LGS	Vigorous exercise time	Non-vigorous exercise time
Within R-sq	0.0225	0.0036	0.0414	0.0234

Table 4. Linear regression with multiple fixed effects on visiting and exercise time (N=1270).

*Standard errors in parentheses. * p<0.1,** p<0.05, *** p<0.01. LGS=local green spaces.*

Discussion

The findings from this study informed long visiting hours to green space possibly lead to long vigorous and non-vigorous exercise time at green space. Neighbourhood diversity moderated the association of perceived quality with daily visit, while single status moderated the association of perceived accessibility with daily visit. Neighbourhood diversity moderated the association of LGS % with choices of car, bus, and walk. Neighbourhood diversity moderated the associations of barriers with hours visiting LGS, the associations of perceived accessibility with vigorous exercise time, and the associations of perceived quality, LGS %, travel duration, and perceived accessibility with vigorous exercise time, respectively. Single status moderated the associations of perceived quality and accessibility with vigorous exercise time, respectively.

Hours visiting local and non-local green spaces vigorous exercise and non-vigorous exercise time concentrated in the areas less than 5 hours. This can be mainly explained by working time and life time. Physiologically, there were an optimal physical activity time for depressive symptoms [67] and comorbid insomnia [68].

The association between geographical features of green spaces and green physical activity time was in line with other studies. For example, a study in Australia indicated that park features and characteristics highly valued for physical activity and social interaction [69]. Socioeconomic factors were associated with distance to local green spaces [70]. The green space is functioned for exercise or sociocultural activities [71]. The spatial inequity of urban green spaces in China could be explained by socioeconomic contexts [72].Size of neighbourhood green spaces possibly increase outdoor walking levels [73].Social setting does not influence individuals' attainment of the psychological outcomes of green exercise participation[74]. The relationships between socioeconomic characteristics and transport modes are complex [75]. Choice of transport modes depend on socio-spatial inequalities of travel time for access to physical activity facilities[76].

Park access was strongly associated with park physical activity [77]. Consistent with previous studies, distance is highlighted in the statistical outcomes. For example, a short distance to a middle-sized green area is appropriate for participation in green exercise[78]. Ecosystem services from green spaces varied by distance to the urban center [79]. Likewise, increased distance from urban green spaces possibly reduce the frequency of green exercise [80]. The duration of visits to urban green spaces was positively associated with mental health and social functioning [81].

Strengths and limitations

This study has several strengths, including the younger and older population. In addition, we included several important moderating factors in the fixed effect models, including single status neighbourhood diversity that had not previously been included in previous studies of this nature.

There are some particularly noteworthy limitations in this study. This study used self-report rather than time series nature of the data. Obviously, the confounding effect of physical work was not carefully considered. In addition, the generalizability of findings could be limited due to studies comprising British full-time employees with age interval from 22 to 65 years. A main limitation of our estimation is the cross-sectional design. Moreover, because only four indicators of geographical features of green spaces are considered with cross-sectional data, the longitudinal relationship should be conducted to discover potential causal links between the associations of interest.

Conclusions

In conclusion, we add to previous findings that neighbourhood diversity and single status mediated associations between geographical features of green spaces and green physical exercise. In addition, geographical features of green spaces are identified significant factors associated with daily visit, choices of transport modes, and visiting and exercise time. The research outcomes highlight the geographical layout of green space in the visiting and exercise time.

doi.org/10.32388/HZNCLH

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Declarations

Funding: No specific funding was received for this work.

Potential competing interests: No potential competing interests to declare.