Objectively measured access to recreational destinations and leisure-time physical activity: associations and demographic moderators in a six-country study

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Keywords

Geographic information systems, Physical activity, Recreation facilities, Parks, Moderation

ABSTRACT

Within the growing body of research linking neighbourhood environmental attributes with physical activity, associations between recreational destinations and non-walking leisure-time physical activity (LTPA) are rarely studied, and to date, not across multiple cities. We examined six potential associations of objectively-measured access to private recreational facilities (e.g., fitness centres, swimming pools) and parks with adults' non-walking LTPA (e.g., swimming, cycling, tennis), using data gathered with consistent methods from adults living in international cities with a range of environment attributes. The potential effects of socio-demographic moderators and between-city variations were also examined. Data from 6725 adults from 10 cities (6 countries) were gathered. Adults were more likely to engage in non-walking LTPA if they had a greater number of private recreational facilities within 0.5 or 1 km of the home, particularly in women, and if they lived closer to a park. The amount of non-zero LTPA was only associated (positively) with the number of recreational facilities within 1km. Relationships between amount of LTPA and park proximity appear complex, with likely contextual and cultural differences. Improving access to private recreational facilities could promote non-walking LTPA, especially in women.

HIGHLIGHTS

- We analysed data from adult residents of 10 environmentally diverse cities
- Likelihood of non-walking LTPA was associated with recreational facility and park access
- Private recreational facilities were more important for women's non-walking LTPA
- Associations of park proximity with non-walking LTPA vary by city and social group

INTRODUCTION

Physical inactivity is estimated to account for 6-10% of major non-communicable diseases worldwide (Lee et al., 2012). It is increasingly recognised that levels of physical activity are associated with characteristics of neighbourhood environments. Cross-sectional associations link a range of perceived- and objectively-measured built environmental attributes with physical activity (Barnett et al., 2017; Duncan et al., 2005; Orstad et al., 2017; Van Cauwenberg et al., 2018). These relationships are often explored using independent indicators of neighbourhood walkability, such as residential density, land use mix, street connectivity and access to local destinations (Barnett et al., 2017; Cerin et al., 2017), or a composite of indicators constructed to form walkability indices (Duncan et al., 2011; Frank et al., 2010), in relation to overall or transport-related physical activity and walking (Bauman et al., 2012; Panter and Jones, 2010).

The relationship between neighbourhood environment and leisure-time physical activity (LTPA) is less studied. LTPA has been defined as '*volitional activity obtained through participation in sports, exercise and recreation at a moderate and/or vigorous intensity level'* (Martin et al., 2014, p1) and can include activities such as walking for recreation, or activities such as swimming, cycling, or jogging that occur in public spaces or at private facilities. As with overall physical activity, higher levels of LTPA are predictive of a lower risk of many types of cancer (Moore et al., 2016), cardio-metabolic diseases (Sofi et al., 2008) and mortality (Arem et al., 2015). There is also evidence that LTPA might be more strongly related to mental health benefits than other physical activity domains (Cerin et al., 2009; Sugiyama et al., 2008).

Neighbourhood environment-LTPA studies have tended to focus on overall LTPA or recreational walking [e.g., (Huston et al., 2003; Sugiyama et al., 2014; Van Dyck et al., 2014, 2013; Witten et al., 2012)]. For example, Van Dyck et al. (2013) explored recreational walking and leisure-time MVPA in four cities (Baltimore, US; Seattle, US; Adelaide, Australia; Ghent, Belgium). They found that environmental indices of perceived 'recreational walking-friendliness' and 'leisure-time activity friendliness' were positively associated with their respective physical activity outcomes, although these associations varied by city. Analysis of data from 12 countries identified a relationship between recreational walking and perceived environmental attributes, such as residential density, land use mix, street connectivity, aesthetics, safety from crime, and park proximity (Sugiyama et al., 2014). There was little variation in associations between countries.

The non-walking component of LTPA includes sport, exercise and other recreational activities (e.g., running, swimming, tennis, yoga). These types of activity often require specific types of environmental support (e.g., access to sport facilities, fitness centres, health clubs and parks) that differ from typical indicators of walkability, which are conceptually and empirically linked to transport physical activity. Related studies have measured perceived access to recreation facilities and produced inconsistent findings. For example, positive associations have been reported between perceived convenience of outdoor sport/fitness facilities (but not indoor facilities) and moderate-to-vigorous LTPA (Cerin et al., 2008), perceived convenience of recreation facilities and vigorous LTPA (Van Dyck et al., 2011), and between perceived access to physical activity facilities and LTPA only for men (Su et al., 2014). Others have found no such associations [e.g., (Humpel et al., 2004)].

A recent systematic review on perceived and objectively-measured built environment attributes and older adults' LTPA reported positive associations of recreational facilities with overall and non-walking LTPA, but not with walking for recreation (Van Cauwenberg et al., 2018). Similarly, the early study of Sallis et al. (1990) identified that objectively measured density of private (pay to use) exercise facilities was greater for adults who reported regular exercise (≥3 sessions/week).

A greater number of studies have explored access to green space, using both perceived and objective indicators of access, but with mixed results. Reviews have reported equivocal evidence for associations between physical activity and access to green space (Lachowycz and Jones, 2011) and to parks (Kaczynski and Henderson, 2007), highlighting variation in measurement of access as a potential explanation. The complexities of green space access measurement and often neglected aspects (e.g., quality, use) are well documented (Ekkel and de Vries, 2017; Gidlow et al., 2018). Schipperjin et al. (2017) examined 6181 adults across 12 cities (in 8 countries) using comparable measures of access found that objectively-measured number of parks within 1 km of the home was associated with greater LTPA and MVPA.

Inconsistent associations between park or green space access and non-walking LTPA may be due in part to different patterns of association across demographic groups (Van Cauwenberg et al., 2018). Hartig et al. (2014), in their review of reviews of natural environments and health, noted that green space-physical activity relationships are likely to vary by population group. Moreover, there are marked international and socio-demographic differences in LTPA participation [e.g.,(Lahti et al., 2016)], which are likely to be even greater when focusing on non-walking LTPA. Both real and perceived access to recreational facilities have been shown to differ between socio-economic groups (Giles-Corti and Donovan, 2002; Powell et al., 2006) and areas (Boakye-Dankwa et al., 2018).

The present study examined associations of objectively-measured access to recreational destinations with adults' non-walking LTPA using data gathered with consistent methods from adult residents of international cities with a diverse range of physical environmental attributes. The potential moderating effects of age, gender, educational attainment and employment status on this relationship, and whether such moderating effects varied by city, were also examined.

METHODS

Study design

The International Physical Activity and Environment Network (IPEN) Adult study investigated the associations between the environment and physical activity in 17 cities across 12 countries, using comparable methods and measures between countries (Kerr et al., 2013). Stratified neighbourhood sampling was used to ensure that study neighbourhoods varied in walkability and socioeconomic status (SES). SES data were obtained for small census-derived geographic units in country (Adams et al., 2014; Frank et al., 2010). For the matching small census units, Walkability index scores were derived using Geographic Information Systems (GIS) from at least two of the following variables: (a) street connectivity, (b) net residential density (ratio of residential units to the land area devoted to residential uses); and (c) land use mix (diversity of land use types), with normalized scores ranging from 0, indicating single use to 1, indicating even distribution of area across several types of uses (e.g., residential, retail, entertainment, institutional). In five countries, retail floor area ratio was also used as a proxy for pedestrian-oriented design. Chosen areas were classified into one of the four types (low/high walkability x low/high SES) and a relatively balanced number of adults were recruited from selected neighbourhoods.

Participants

The present analysis of data collected as part of the wider IPEN Adult study included data from 10 cities across six countries in which data for all required exposure and outcomes variables were available and comparable [Curitiba, Brazil (BR); Olomouc, Czech Republic (CZ); Aarhus, Denmark (DK); North Shore, Waitakere, Wellington, and Christchurch, New Zealand (NZ); Stoke-on-Trent (UK);

Seattle/King County and Baltimore (US)]. All environmental exposure measures were derived using participants' geocoded residential street address.

Measures

Objective measures of access to recreational destinations

As described by Adams et al. (2014), objective measures of recreational facilities were developed following an intensive process to coordinate efforts across country sites. Briefly, GIS templates were developed by the IPEN coordinating centre (in coordination with country teams) for each of the environmental constructs of interest. GIS templates included operational definitions of environmental constructs and specifics on how to calculate metrics for recreational facilities and parks. Operational definitions provided positive and negative examples of recreational facilities and parks to ensure that all countries were consistent in what IPEN considered a recreational facility or park. Country teams completed their work following these templates and contacted the IPEN coordinating centre to discuss issues or for clarifications, as needed. Within each template, a series of required questions probed each team's adherence to operational definitions and methods for calculating variables. The IPEN coordinating centre preliminarily reviewed these answers prior to accepting data from a country, and once all countries provided responses, two experts in the field conducted a formal comparability evaluation. Subsequently, country datasets underwent data cleaning. At any time throughout this process country teams could be asked to revise their definition, approach, or calculations to ensure comparability with other sites. The comparability evaluation noted that 6 out of 11 country sites (10 cities) had data on recreational facilities judged comparable by the process. Data sources included business listings, phone book listings, marketing firm's address lists, other online internet sources, and parcel data. The comparability evaluation also found that country sites were able to identify park datasets for these 10 cities with sources varying from government supplied lists to aerial photography.

Two indicators were used to reflect access to recreational facilities:

i) Access to private recreation facilities was measured as the number of private recreational facilities within 0.5km and 1km street-network buffers of participants' home addresses. A private recreation facility was defined as one where participants could usually be physically active and examples included: fitness centres, health clubs, tennis centres, swimming pools, golf courses, outdoor arenas and campsites. Public parks were not considered private recreation locations. Facilities were identified from region-specific spatial datasets.

ii) Access to parks was calculated as the distance in metres from each participant's home address to the nearest park (of any size) along the street network. A public park was identified from region-specific spatial datasets using the following criteria: a government agency (i.e., federal, local, regional, municipal level; parks or planning departments; etc.) considered the space a park; the space was physically accessible to the public (e.g., free/open access); and/or open beaches and wooded areas functioning as public parks. The following areas were not considered public parks: green space maintained by a homeowner's association, part of an apartment complex playground, an unimproved open space with 'no use designated', or a proposed park, or a school, religious facility, or golf courses. Distance to nearest park, rather than park area or count, was used to reduce the risk using an indicator of access that acted as a proxy for general walkability characteristics, such as land use mix or street connectivity. The network analyst extension in ESRI's ArcGIS was used to measure distance between a participant's home address (origin point) and the point at which the nearest park polygon (using a 15-metre buffer around the park) intersected with the road network (destination point). Because this method typically resulted in multiple points for a single park, all points were accepted as representative of where someone could enter the park.

Non-walking leisure-time physical activity

Self-reported non-walking leisure-time physical activity (LTPA) was derived from the International Physical Activity Questionnaire-Long [IPAQ-L (Craig et al., 2003)]. Total weekly minutes of non-walking LTPA were calculated as the product of the number of days and usual minutes per day of bouts of LTPA lasting 10 minutes or more, excluding walking (of at least 10 minutes), in the last week. Given the large number of participants reporting zero non-walking LTPA accumulated in 10+ minute bouts (n=1826, 27.2%) in the past week, we used two outcome variables: Participation vs. non-participation in non-walking LTPA lasting 10 minutes or more in the last week (dichotomous variables - participation=1, non-participation=0); weekly minutes of non-walking LTPA in participants who did some, referred to as non-zero weekly minutes of non-walking LTPA (continuous variable). This type of approach addresses the statistical issues associated with continuous or discrete outcome variables with an excessive number of zero values (Sugiyama et al., 2014) and, at the same time, allows the identification of potential environmental determinants of LTPA adoption (dichotomous non-walking LTPA variable) and amount of LTPA in adopters (non-zero continuous non-walking LTPA variable) (Cerin et al., 2010).

Socio-demographic characteristics

Age, gender, educational attainment ('less than high school graduate', 'high school graduate' and 'college degree or higher'), employment status ('employed' and 'not employed') and marital status ('married/living with partner' and 'not living with partner') were self-reported.

Data Analytic Plan

Descriptive statistics were computed for the whole sample and by city. Associations of objective measures of access to recreational facilities with non-walking LTPA outcomes and moderating effects of age, gender, education and employment status were estimated using generalized additive mixed models [GAMMs (Wood, 2006)] accounting for clustering effects at the administrative unit level (Cerin et al., 2014). GAMMs accommodate outcomes with various distributional assumptions (e.g., binary or positively skewed) when data are correlated (i.e., derived from participants living in pre-selected administrative units). They can also model curvilinear relationships using smoothing terms. GAMMs with binomial variance and logit link functions were used for the dichotomous non-walking LTPA measure (participation in non-walking LTPA), while GAMMs with Gamma variance and logarithmic link functions were used for the continuous non-walking LTPA measure (non-zero weekly minutes of non-walking LTPA). The reported antilogarithms of the regression coefficients of these two sets of models represent the odds of participating vs. not participating in non-walking LTPA (odds ratios) and the proportional increase in non-zero weekly minutes of non-walking LTPA associated with a 1 unit increase in the environmental predictor, respectively.

Main-effect GAMMs estimated the dose-response relationships of all objective measures of access to recreational destinations with the non-walking LTPA outcomes, adjusting for city, socio-demographics (i.e., age, gender, educational attainment, employment status and marital status) and administrative unit-level SES. For all main effects, a two-tailed probability level of 0.05 was adopted. Curvilinear relationships of environmental attributes with outcomes were estimated using non-parametric thin-plate splines in GAMMs (Wood, 2006). Smooth terms failing to provide sufficient evidence of a curvilinear relationship (based on a 10-point difference in Akaike Information Criterion, AIC between GAMMs) were replaced by simpler linear terms (Wood, 2006). Separate GAMMs estimated environmental variables by selected socio-demographics (i.e., age, gender, education and employment status) interaction effects by adding a single two-way interaction term to the main effects models. Another set of models estimated whether moderating effects of environmental variables by socio-demographic characteristics on non-walking LTPA outcomes varied by city. This was done by adding three- or four-way environmental variable by socio-demographics by city interaction terms to the simpler models with two-way interactions. The significance of the interaction effect was evaluated by comparing AIC values of models with and without a specific interaction term. An interaction effect was deemed significant if it yielded an AIC value of 10 or more units smaller than the main effect model, indicating no support for the simpler main-effect model (Burnham and Anderson, 2002). All significant interaction effects from the single-interaction models were included in final interaction-effect GAMMs. These analyses tested for the presence of moderating effects on the multiplicative scale (odds ratio and proportional increase in outcome(s)).

Significant interaction effects were explored by computing age-, gender-, education- or employment status-specific associations by city (as appropriate) using linear combinations of regression coefficients based on the pooled data. Age-specific associations were estimated at average, 1 standard deviation (SD) below, and 1 SD above values of age. Environmental variables were centered around their mean. As only 149 cases (2.21%) had missing data, data analyses were performed on complete cases (Cerin et al., 2014). All analyses were conducted in R (Core R Team, 2013) using the packages 'mgcv' (Wood, 2006), 'multcomp' (Bretz et al., 2010) and 'forestplot' (Gordon, 2017).

RESULTS

Table 1 shows the overall and city-specific descriptive statistics for socio-demographics and weekly minutes of non-walking LTPA. The sample consisted of 6725 participants who were predominantly women (54%), had less than a college university degree (55%), were employed (78%), married (60%) and from high income SES (52%). The mean age was 42 years (SD=13, range: 18 – 66). Overall, participants engaged in 233 min/wk (SD=330), with a median of 120 min/week (IQR=310) of non-zero LTPA; and over one-quarter did not engage in any LTPA (27%).

INSERT TABLE 1 ABOUT HERE

Table 2 shows overall and city-specific descriptive statistics for access to recreational facilities. The mean number of recreational facilities within 1 km from home was around 3, ranging from 1.0 in Christchurch (NZ) to 6.4 in Olomouc (CZ). Within 0.5 km, the mean number of facilities was less than 1, ranging from 0.0 in Waitakere (NZ) to 1.9 in Olomouc (CZ). The mean distance to the nearest park was 440 metres (SD=400 metres) and varied widely between cities, with the longest distances observed in Baltimore (US, 650m) and Olomouc (CZ, 660m), and the shortest in Northshore (NZ, 240m). There was a moderate-strong positive correlation between number of recreational facilities within 0.5 km and 1 km (rho=.675), and weak negative correlations between distance to the nearest park and number of recreational facilities (within 0.5 km, rho=-.205; within 1.0 km, rho=-.203).

INSERT TABLE 2 ABOUT HERE

Associations of age, gender, education and employment status with non-walking LTPA outcomes

Age was negatively curvilinearly associated with the odds of participation in non-walking LTPA (Figure 1). A stronger negative relationship between age and the odds of participation in non-walking LTPA was observed among respondents aged 20 to 40 years. However, age was not related to the amount of non-walking LTPA (min/week) in those engaging in some LTPA (i.e., non-zero). Higher educational attainment and being employed were associated with higher odds of participation in non-walking LTPA. However, in those who engaged in this type of LTPA, higher educational attainment and being employed were predictive of fewer weekly minutes of LTPA (Table 3). While no significant gender differences were found in the odds of participation in non-walking LTPA, women who participated in non-walking LTPA reported fewer weekly minutes than men.

INSERT TABLE 3 & FIGURE 1 ABOUT HERE

Associations between objective measures of access to recreational destinations and non-walking LTPA outcomes (main effects)

Significant positive associations were found between the number of private recreational facilities within 1 km (OR = 1.035; 95% CI: 1.015, 1.055; p <0.001) and 0.5 km from home (OR = 1.106; 95% CI: 1.046, 1.168; p <0.001) and the odds of engaging in non-walking LTPA. Among those engaging in non-walking LTPA, the number of private recreational facilities within 1km (e^b = 1.012; 95% CI: 1.004, 1.020; p = 0.003), but not within 0.5 km from home (e^b = 1.014; 95% CI: 0.991, 1.037; p =0.226), was positively associated with non-zero weekly minutes of non-walking LTPA.

Distance to the nearest park from home (in 100 m units) was negatively related with the odds of engaging in non-walking LTPA (OR = 0.978; 95% CI: 0.962, 0.995; p = 0.011), but unrelated to non-zero weekly minutes of non-walking LTPA (e^b = 0.997; 95% CI: 0.989, 1.005; p =0.457).

Moderating effects of age, gender, education, employment status and city on the associations between objective measures of access to recreational destinations and non-walking LTPA outcomes

We found only one significant interaction effect on the associations between number of private recreational facilities and non-walking LTPA outcomes (Table 4). Gender moderated the associations of the number of recreational facilities within 1 km of the home and non-zero weekly minutes of non-walking LTPA. While no significant association was found for men (e^b = 1.006; 95% CI: 0.995, 1.017; *p* = 0.321), a positive association was observed for women (e^b = 1.018; 95% CI: 1.007, 1.028; *p*<0.001).

The moderating effect of education on the association of distance to the nearest park from home with weekly minutes of non-walking LTPA was significant in Baltimore only (Table 4; Supplementary Table 1). While distance to park tended to be negatively associated with weekly minutes of non-walking LTPA in respondents with less than 'high school' education (e^b = 0.801; 95% CI: 0.637, 1.006; *p* = 0.058), it tended to be positively associated in those with 'high school or some graduate' education (e^b = 1.028; 95% CI: 0.999, 1.058; *p* = 0.063). Finally, a four-way interaction effect of distance to park by gender by employment status by city was found for weekly minutes of non-walking LTPA (Table 4). Employment status was a moderator of the association between distance to park and weekly minutes of non-walking LTPA in men from Curitiba (BR) and Baltimore (US) (Supplementary Table 2), and in women from Waitakere (NZ) and Seattle (US) (Supplementary Table 3). A negative association was found in non-working men from Curitiba, while in Baltimore, non-working men showed a positive association and working men tended to show a negative association (Figure 2). In non-working women from Waitakere and Baltimore the association tended to be positive, while non-working women from Seattle showed a negative association (Figure 3).

INSERT TABLE 4, FIGURES 2 & 3 ABOUT HERE

DISCUSSION

We report findings from adults residing in 10 cities across six countries on the associations of objectively measured number of private recreational facilities near the home (within 0.5 and 1 km) and park proximity with non-walking LTPA, potential socio-demographic moderators and variation in moderators by city. Pooled analyses indicated that adults were more likely to engage in non-walking LTPA if they had a greater number of private recreational facilities within 0.5 or 1 km of the home, and if they lived closer to a park. Having more private recreational facilities within 1 km of home was associated with higher weekly amount of LTPA (among those who engaged in some; i.e., non-zero weekly minutes of LTPA), but living near a park was unrelated to weekly amount of LTPA. Specifically, regression model estimates indicated that, on average, adult residents of cities in which the number of private recreational facilities close to home was highest (Waitakere and Christchurch, NZ) would be ~21% more likely to participate in non-walking LTPA than residents of the city where number of proximal facilities was lowest (Olomouc, CZ). The average difference in the odds of participation in non-walking LTPA between residents of cities with the longest (Olomouc, CZ) and shortest (North Shore, NZ) distances to parks was ~10%. In those who did engage in non-walking LTPA, the number of weekly minutes was positively associated with the number of recreational facilities within 1 km of the home only (not within 0.5 km and not park proximity). The estimated difference in non-zero minutes of non-walking LTPA between those who lived in the cities with the highest versus lowest number of private recreational facilities close to the home was ~17 min/week. Moderating effects of socio-demographics factors were mainly observed for the non-walking LTPA-park proximity relationship.

Access to private recreational facilities

Associations between the number of recreational facilities near the home and non-walking LTPA were significant and appeared to be similar across cities. Previous studies have largely relied on perceived accessibility to recreational facilities, ranging from trails to outdoor facilities or indoor gyms, in examining associations with measures of overall LTPA. Perceived convenience of the types of private recreational facilities we included (i.e., sport/fitness facilities) has been positively associated with LTPA in some studies [moderate-to-vigorous (Cerin et al., 2008); vigorous (Van Dyck et al., 2011); meeting physical activity recommendations through LTPA (Huston et al., 2003)], but not in other studies [recreational walking (Kondo et al., 2009)]. One study of Chinese older adults used independent environment audits to objectively determine access to recreational facilities and found that the odds of non-walking LTPA participation were positively associated with the number of community centres, sports fields, parks and public facilities within 400 m from home (Cerin et al., 2013). The 1990 study of San Diego residents similarly suggested a greater density of pay exercise facilities within 1-5 km of the home among those who engaged in three or more exercise sessions per week (Sallis et al., 1990).

All of the above cited studies focused on one city only. The present study was conducted across 10 cities from different regions, using consistent methods that included objective, GIS-derived indictors of access to recreational destinations and specificity in the type of LTPA outcome most appropriate to such destinations (non-walking). Findings from this multi-country study further indicate that having private recreational facilities in the neighbourhood can promote non-walking recreational physical activity.

Commonly reported barriers to LTPA include lack of time, weather, tiredness and lack of facilities, and can vary between population groups (Cerin et al., 2010; Reichert et al., 2007; Trost et al., 2002). Cerin et al. (2010) reported that 'lack of facilities' was a significant correlate of moderate-to-vigorous LTPA, with a trend towards this association being more important in women. Our similar observation that women's non-walking LTPA appears more dependent on having private recreational facilities close to home (compared with men) could be a reflection that women within our sample age might have greater engagement in other activities (e.g., domestic responsibilities) than men and that convenient access to facilities is more important for women. Women may also be more concerned than men about personal safety when participating in LTPA and, thus, might be more dependent on the availability of private recreation facilities. This is an important finding that may suggest ways to address the lower levels of LTPA in women compared with men [e.g., (Azevedo et al., 2007; Lahti et al., 2016)]. Moreover, the lack of moderation by age and education suggests that having more recreational facilities nearby is beneficial regardless of age and socio-economic status.

Park proximity

Living closer to a park was significantly associated with a higher likelihood of engaging in non-walking LTPA. The park proximity-weekly minutes of non-walking LTPA association was not moderated by socio-demographic factors but by city. It was only evident in Baltimore (US), where adults with lower education who lived closer to a park tended to report more non-walking LTPA, but the opposite was true in those with 'high school or some graduate' education (i.e., worse proximity was related to more non-walking LTPA). This could reflect a greater dependence by lower SES groups on free to use/publicly accessible places, such as neighbourhood parks, for non-walking LTPA. Thus, poor proximity to parks may be more of a barrier to those of lower SES such that provision of better access to public parks may help reduce socio-economic (educational level) differences in LTPA participation observed here and elsewhere (in certain environments/contexts). It is, however, unclear why this distinction would only be significant for the Baltimore region of the US.

There were socio-economic, gender and city moderation effects for the park proximity-weekly minutes of non-walking LTPA relationship. The relationship was in the expected direction (of lower non-walking LTPA with greater distance to the nearest park) for unemployed men in Curitiba (BR) and Arhus (DK), employed men in Baltimore (US) and unemployed women in Seattle (US). The associations were in the opposite direction for unemployed men and women in Baltimore, and unemployed women in Waitakere. It is unclear what might explain these city-specific moderating effects. A more general interpretation is that factors potentially influencing amount of non-walking

LTPA are complex, may depend on the local context (e.g. social norms and culture), and justify further study.

Our data therefore, suggest that living closer to a park might encourage people to use it for non-walking LTPA, although it is possible that those more likely to engage in such activities chose to live near to parks. The extent to which park proximity can influence the amount of non-walking LTPA undertaken varies by city, gender and socio-economic status. This contrasts with a previous IPEN study of various measures of park access and physical activity in 12 cities across eight countries (Schipperijn et al., 2017). The authors reported a very small, but significant association between distance to the nearest park and with the likelihood of engaging in leisure-time walking, but not 'other LTPA' (i.e., non-walking). Overall, the various moderating effects observed in the present study offer a somewhat confusing picture that is consistent with the uncertainty in the natural environment-physical activity literature relating to LTPA and park access (Kaczynski and Henderson, 2007) and the variation of such associations by population (Hartig et al., 2014). Compared with many studies, we had greater specificity in our indicators of park access (objectively defined distance to the nearest) and physical activity (non-walking LTPA). However, we did not have data on park facilities and whether the non-walking LTPA was park-based, which would allow more confident inferences to be drawn.

Figures 2 and 3 offer some insight into the inconsistent findings from prior single-city studies regarding park access and physical activity. The few significant city-specific results regarding park proximity and non-zero minutes of non-walking LTPA (Figures 2 and 3) contrast with the significant association in the pooled analyses. Of course, those figures report subgroup analyses by working and non-working status that reduce statistical power substantially, thus exaggerating the problem. However, a core rationale for pooled international analyses was that only international data could provide the full range of environmental variation needed to estimate accurate relationships and effect sizes.

The demographics of participation showed some expected patterns of a reducing likelihood of non-walking LTPA with increasing age (greatest reductions in younger-middle aged) and in lower educated and the unemployed. These findings are generally consistent with reviews (Kelly et al., 2016; Trost et al., 2002), but also demonstrate international consistency in these demographic correlates of non-walking LTPA. The lack of clear age and employment status by environmental attribute moderation effects on LTPA suggests that manipulating these features (i.e., improving access to recreational facilities and parks) is unlikely to affect differences in non-walking LTPA participation between various age and socio-economic groups. Moreover, the lack of age and socio-economic status associations with minutes of LTPA might be because non-walking LTPA accounts for a relatively small proportion of overall LTPA [e.g., (Abu-Omar and Rütten, 2008; Cochrane et al., 2009) and for some groups, such as older adults, walking might be the primary form of LTPA (Eyler et al., 2003).

STRENGTHS AND LIMITATIONS

Strengths of this study included the application of consistent design and comparable measurements of physical activity outcomes and objectively determined environmental indicators to a large sample of adults residing in 10 cities, which are diverse in terms of the distribution of recreational facilities. Limitations are recognised. First, we are limited to cross-sectional analyses, which prevent assertions of causality. Second, although self-reported physical activity was necessary to delimit our analyses to the specific domain of non-walking LTPA, there are associated issues of recall bias, social desirability bias and the challenges of accurate, subjective quantification of activity volume (Prince et al., 2008). There is also evidence that different countries and linguistic groups may interpret the IPAQ items in different ways, which leads to culture- or country-specific biases in physical activity measurement when using self-reports (Cerin et al., 2016). However, this bias may not be serious for the dichotomous measure (participation vs non-participation). Third, the parks (to which distance was measured) can vary in size and the facilities/amenities. These were not measured in this study, but having certain facilities/amenities (multiuse trail) in parks have been correlated with greater park-based physical activity (Kaczynski and Henderson, 2008; Kaczynski *et al.*, 2014). Fourth, we used 0.5 and 1.0 km buffers to explore accessibility of recreational facilities, which are typical of neighbourhood environment-physical activity research. These were intended to represent walkable (5- and 10-minute walk, respectively) and, therefore, convenient distances from the home that might make people more likely to access recreational facilities for LTPA. It is possible that some people are willing to travel further to access this type of recreational facility, which would require considerably larger buffer sizes. Fifth, it is possible that individuals travelled to recreational destinations from work, but this could not be explored (as we did not know the locations of employment). Finally, we used data from middle- and high-income countries, not low-income countries.

CONCLUSIONS

Data from this large sample of adults from a diverse range of international cities (10 cities, 6 countries) showed that adults were more likely to engage in non-walking LTPA if they had a greater number of private recreational facilities within 0.5 or 1 km of the home and lived closer to a park. For those who did some non-walking LTPA, weekly amount of LTPA was positively associated with the number of recreational facilities within 1 km (not within 0.5 km and not with park proximity). Sociodemographic and city-level moderating effects indicated that the number of recreational facilities in the neighbourhood should have a similar influence on non-walking LTPA across different cities, but may be more important for women than men, thus offering a potential means of addressing the gender difference in LTPA participation. The relationship between amount of non-walking LTPA and park proximity is more complex. The various and contrasting moderating effects support the notion that green space-physical activity associations are likely to depend on contextual and cultural differences that need to be examined in future studies.

ETHICAL APPROVAL – redacted for blind review

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CONFLICT OF INTEREST STATEMENT

All authors declare that they have no competing interests.

AUTHOR CONTRIBUTIONS

JS and EC conceived the wider IPEN Adult study from which these data were sourced. All authors contributed to the analysis design (variable selection) and EC determined the statistical methods. EC and MA performed data analysis. CG and EC led manuscript preparation. All authors contributed to and approved the final manuscript.

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Table 1: Sample characteristics: socio-demographic information and non-walking leisure-time physical activity (LTPA)

	All cities	Curitiba (BR)	Olomouc (CZ)	Aarhus (DK)	North Shore (NZ)	Waitakere (NZ)	Wellington (NZ)	Christchurch (NZ)	Stoke-on-Trent (UK)	Seattle (US)	Baltimore (US)
N	6725	697	330	642	511	512	496	495	843	1287	912
Age, Mean (SD)	42 (13)	41 (13)	38 (15)	39 (14)	41 (12)	41 (12)	39 (13)	42 (13)	43 (13)	44 (11)	47 (11)
Gender, % men	45.9	47.1	37.3	43.3	36.1	39.3	48.8	44.2	43.9	54.8	47.7
Education											
% less than HS	11.0	28.8	22.0	7.5	3.8	5.1	0.8	10.7	34.0	1.3	2.0
% HS/grad	44.2	32.4	45.8	44.5	57.9	64.2	47.0	57.3	52.0	35.5	30.4
% grad or more	44.7	38.7	32.2	48	38.3	30.7	52.2	32.0	14.1	63.2	67.6
Job, % working	78.3	77.6	77.3	74.6	77.7	84.0	86.7	79.6	64.4	81.3	82.6
Marital Status, *% married*	60.3	58.1	58.4	65.4	70.4	74.2	56.7	55.4	44.8	63.2	60.5
SES, % high income	52.5	49.8	59.4	56.1	66.7	41.0	50.0	49.7	52.9	51.3	52.5
Non-zero LTPA (min/wk) [a]											
Mean (SD)	233.7 (330.7)	137.9 (246.6)	332.7 (386.9)	438.0 (470.2)	173.2 (252.2)	167.5 (250.1)	275.1 (320.6)	166.8 (215.7)	201.5 (336.5)	51.4 (328.1)	218.7 (307.4)
Median (IQR)	120 (310)	40 (200)	210 (476)	285 (480)	90 (240)	90 (240)	180 (320)	90 (258)	60 (270)	150 (319)	120 (300)
% zero min/wk[a]	27.2	44.8	23.6	8.7	28.6	25.8	15.5	32.9	43.2	19.8	26.6

Notes: BR: Brazil; CZ: Czech Republic; DK: Denmark; NZ: New Zealand; HS=high school; SD = standard deviation; [a] minutes of ≥10-minute bouts.

Table 2. Sample characteristics: objective measures of access to recreational destinations

	All cities	Curitiba (BR)	Olomouc (CZ)	Aarhus (DK)	North Shore (NZ)	Waitakere (NZ)	Wellington (NZ)	Christchurch (NZ)	Stoke-on-Trent (UK)	Seattle (US)	Baltimore (US)
N	6725	697	330	642	511	512	496	495	843	1287	912
Number of recreational facilities											
1 km buffer											
Mean (SD)	2.9 (4.1)	4.7(6.7)	6.4 (6.0)	5.4 (4.9)	1.8 (2.7)	1.7 (1.8)	3.4 (4.2)	1.0 (1.1)	1.9 (1.3)	2.5 (3.2)	2.0 (3.6)
Median (IQR)	1.0 (4.0)	2.0 (4.0)	4.0 (8.0)	5.0 (8.0)	1.0 (3.0)	1.0 (3.0)	1.0 (4.0)	1.0 (1.0)	2.0 (2.0)	1.0 (4.0)	1.0 (2.0)
0.5 km buffer											
Mean (SD)	0.8 (1.4)	1.3 (1.9)	1.9 (2.1)	1.4 (1.8)	0.4 (0.9)	0.0 (0.0)	0.9 (1.3)	0.3 (0.4)	0.6 (0.8)	0.8 (1.4)	0.6 (1.5)
Median (IQR)	0.0 (1.0)	0.0 (2.0)	1.0 (3.0)	0.0 (3.0)	0.0 (1.0)	0.0 (0.0)	0.0 (1.0)	0.0 (1.0)	0.0 (1.0)	0.0 (1.0)	0.0 (1.0)
Distance to nearest park (in 100 m unit)											
Mean (SD)	4.4 (4.0)	3.6 (2.8)	6.6 (5.1)	3.9 (3.8)	2.4 (1.9)	4.6 (3.6)	3.5 (3.0)	3.5 (2.6)	3.6 (2.8)	4.7 (3.7)	6.5 (6.3)
Median (IQR)	3.4 (4.1)	2.9 (4.3)	5.1 (4.9)	3.0 (3.3)	1.9 (2.8)	4.1 (5.3)	3.2 (3.8)	3.0 (3.3)	2.8 (3.4)	3.9 (3.9)	4.5 (5.6)

Notes: BR: Brazil; CZ: Czech Republic; DK: Denmark; NZ: New Zealand; SD = standard deviation; IQR = interquartile range.

Table 3: Associations of age, education, gender and employment status with non-walking leisure-time physical activity (LTPA) outcomes

Socio-demographic factor	Participation in non-walking LTPA[a] (reference: non-participation) (n=6575)		Non-zero weekly minutes of non-walking LTPA[b] (n=4789)	
	OR (95% CI)	p	e^b (95% CI)	p
Age	F(1.789, 6570)=13.08[c] (see Figure 1)	<0.001	1.000 (0.998, 1.003)	0.690
Education (reference: less than high school graduate)				
High school graduate and/or some college	1.378 (1.138, 1.669)	0.001	0.922 (0.817, 1.040)	0.186
College degree or higher	2.049 (1.658, 2.531)	<0.001	0.836 (0.738, 0.948)	0.005
Gender (reference: men)				
Women	0.985 (0.876, 1.107)	0.797	0.922 (0.869, 0.978)	0.007
Employment status (reference: not working)				
Working	1.192 (1.034, 1.373)	0.015	0.911 (0.844, 0.982)	0.014

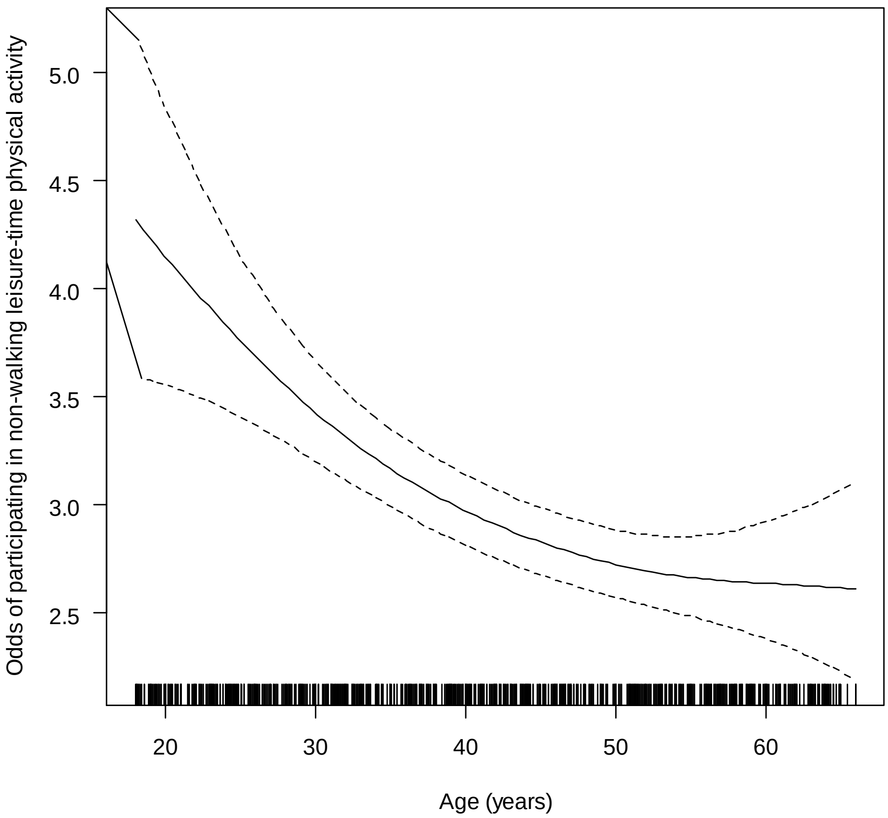
Notes. OR = odds ratio; 95% CI = 95% confidence interval; e^b = antilogarithm of regression coefficient. All regression coefficients are adjusted for respondents' age, gender, marital status, education, employment status and administrative-unit socio-economic status. [a] Generalized additive mixed model (GAMM) with binomial variance and logit link functions. [b] GAMM with Gamma variance and logarithmic link functions, for which e^b is interpreted as the proportional increase in LTPA associated with a 1 unit increase in the predictor. [c] Curvilinear relationship: the F-test refers to the significance of the smooth term.

Table 4: Summary results of moderating effects of age, education, gender, employment status and city on the associations of objectively measured access to recreational destinations with non-walking leisure-time physical activity (LTPA) outcomes[a]

Environmental attribute	Non-walking LTPA outcome	Age	Education	Gender	Job	City	Age x Gender	Gender x Job	Gender x City	Age x City	Educ x City	Age x Gender x City	Gender x Job x City
Number of recreational facilities (1km buffer)	Participation	17.5	7.2	2.6	2.9	147.3	10.2	1.8	29.2	13.4	-1.5[b]	33.0	70.0
	Non-zero min/week	8.2	4.9	**<u>-12.5</u>**	0.4	20.8	2.2	2.6	8.8	0.6	25.9	13.5	7.6
Number of recreational facilities (0.5km buffer)	Participation	8.8	2.3	2.5	2.1	143.5[c]	7.0	4.8	42.8[c]	38.6[c]	26.8[c]	32.5[c]	78.7[c]
	Non-zero min/week	5.7	6.6	-1.1	1.4	27.2[c]	0.8	-0.7	12.7[c]	5.2[c]	11.8[c]	-1.4[c]	3.4[c]
Distance to nearest park	Participation	0.4	3.1	3.3	4.0	116.8	2.2	5.7	66.3	56.9	23.4[b]	45.3	45.5
	Non-zero min/week	3.5	3.0	10.8	-7.1	**-12.6**	2.0	**-27.5**	**-24.5**	-5.5	**<u>-19.7</u>**	6.3	**<u>-10.4</u>**

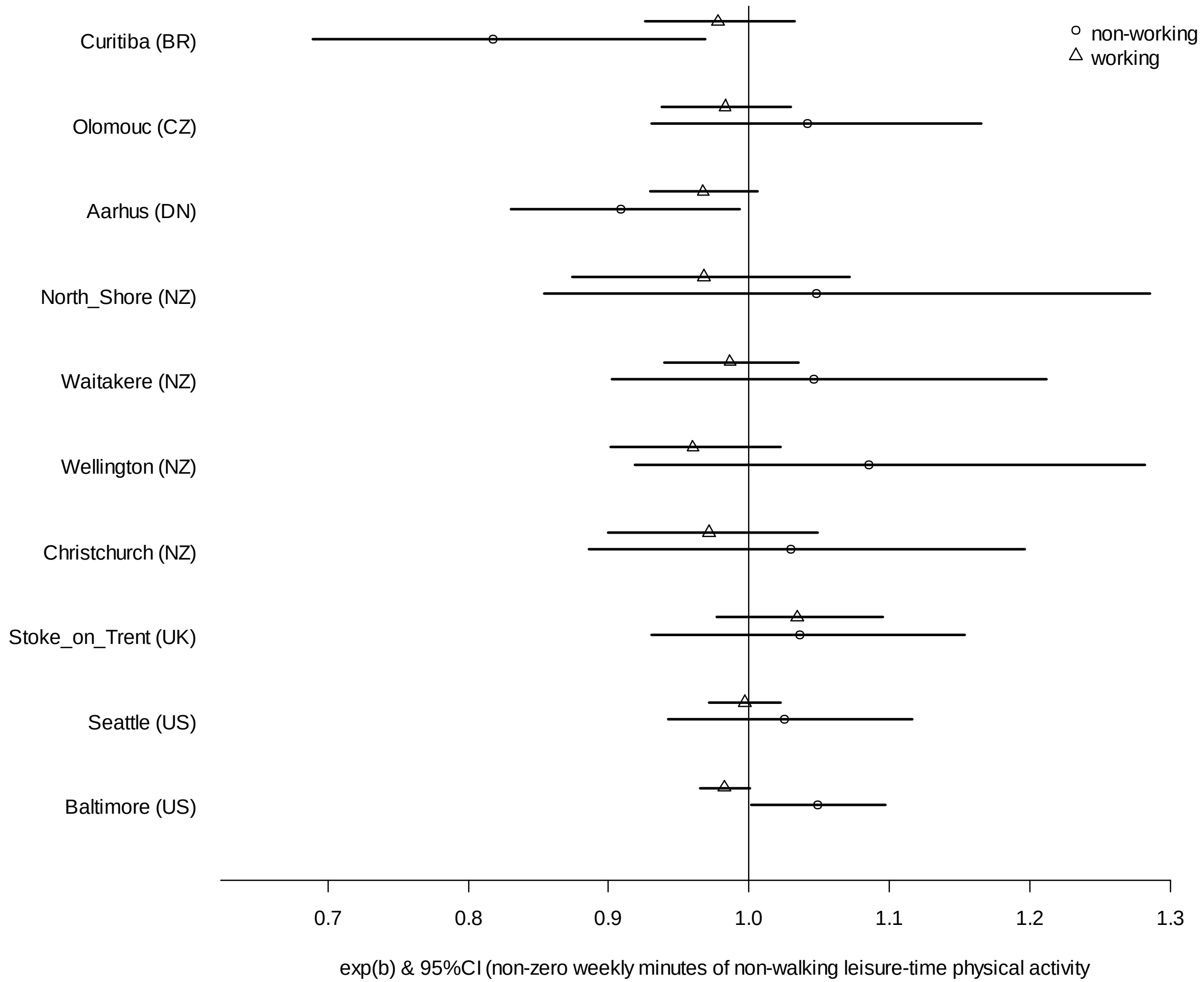
Notes. LTPA = leisure-time physical activity. [a] Values represent differences between Akaike Information Criterion values of more complex (higher order) interaction-effect model and main effect or less complex (lower order) interaction model. Values smaller than -10 are indicative of support for the more complex model (in bold). Underlined values = highest-order significant interaction effects needing probing. [b] estimated with education categories "less than high school" and "high school or some graduate education" collapsed due to non-convergence. [c] estimated excluding Waitakere due to no variability in environmental attribute.

Figure 1: Relationships between age and the odds of participating in non-walking leisure-time physical activity



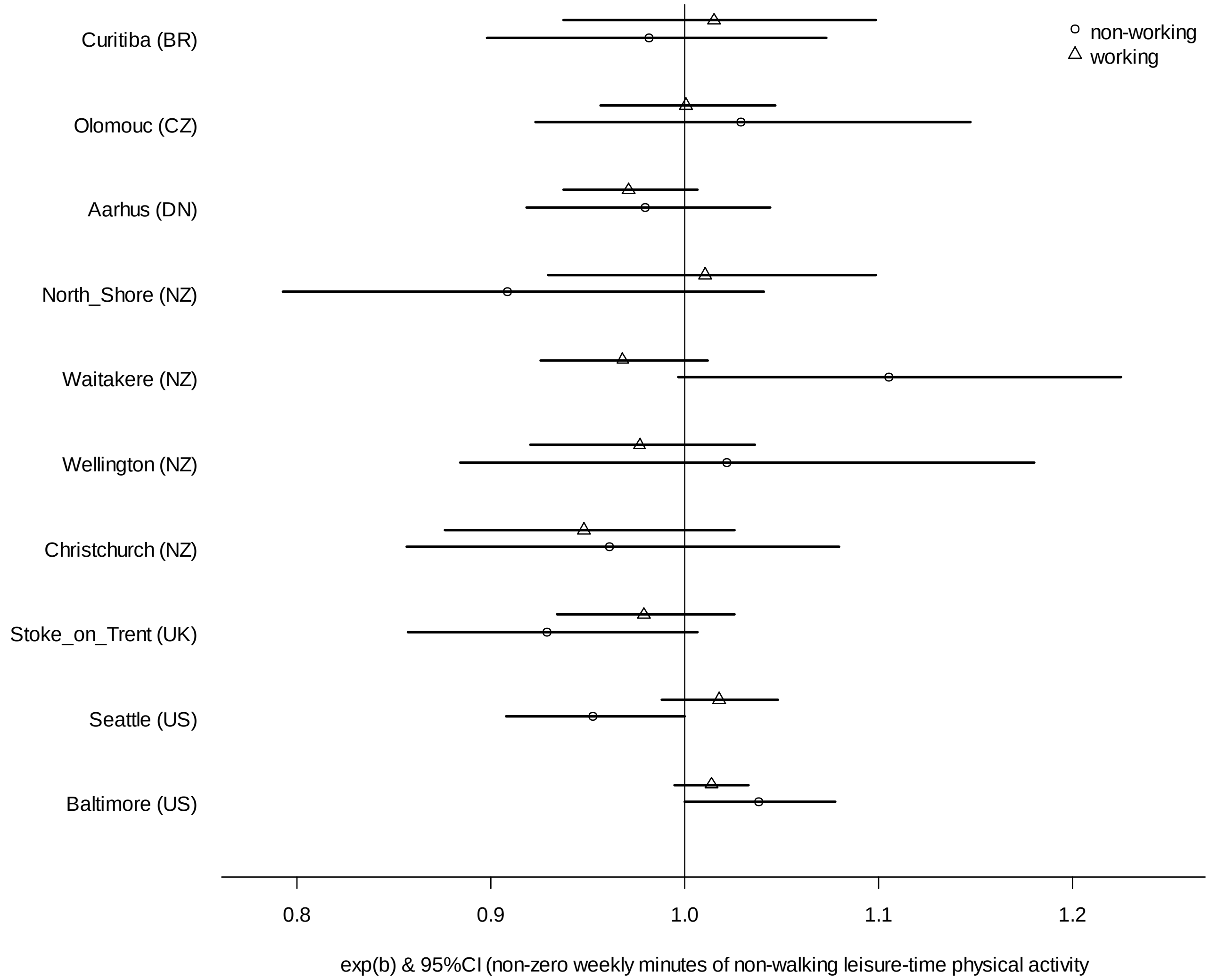
Note. The solid line represents point estimates (and dashed line their 95% confidence intervals) of the odds of participating in non-walking leisure-time physical activity. These estimates were computed at average values of other covariates.

Figure 2: Associations of distance to nearest park (100m) with non-zero weekly minutes of non-walking leisure time physical activity by employment status and city in men



Note. Estimates were computed at average values of other covariates.

Figure 3: Associations of distance to nearest park (100m) with non-zero weekly minutes of non-walking leisure time physical activity by employment status and city in women



Note. Estimates were computed at average values of other covariates.

Supplementary Table 1: Associations of distance to park with non-zero weekly minutes of non-walking leisure time physical activity by educational attainment and city

City	Age	e^b	95% CI	p-value	p-value of interaction
Curitiba (BR)	< High school	1.022	0.949, 1.100	0.568	
	High school	0.995	0.931, 1.064	0.894	0.606
	Graduate	0.953	0.893, 1.017	0.149	0.164
Olomouc (CZ)	< High school	0.984	0.921, 1.051	0.630	
	High school	1.028	0.981, 1.078	0.242	0.283
	Graduate	0.961	0.916, 1.009	0.114	0.578
Aarhus (DK)	< High school	0.942	0.858, 1.033	0.203	
	High school	0.965	0.931, 1.001	0.056	0.622
	Graduate	0.968	0.934, 1.001	0.055	0.603
North Shore (NZ)	< High school	0.993	0.718, 1.373	0.965	
	High school	0.955	0.884, 1.031	0.240	0.819
	Graduate	1.011	0.926, 1.103	0.810	0.916
Waitakere (NZ)	< High school	1.027	0.890, 1.185	0.716	
	High school	0.994	0.955, 1.033	0.753	0.664
	Graduate	0.983	0.930, 1.039	0.544	0.576
Wellington (NZ)	< High school	1.211	0.330, 4.451	0.772	
	High school	0.981	0.926, 1.039	0.518	0.751
	Graduate	0.984	0.929, 1.042	0.580	0.754
Christchurch (NZ)	< High school	0.941	0.829, 1.068	0.348	
	High school	0.958	0.900, 1.020	0.183	0.800
	Graduate	0.991	0.905, 1.085	0.843	0.517
Stoke-on-Trent (UK)	< High school	0.977	0.899, 1.063	0.589	
	High school	1.017	0.977, 1.058	0.407	0.389
	Graduate	0.947	0.877, 1.023	0.169	0.589
Seattle (US)	< High school	1.047	0.806, 1.359	0.732	
	High school	1.019	0.985, 1.053	0.274	0.840
	Graduate	0.995	0.973, 1.016	0.616	0.702
Baltimore (US)*	< High school	0.801	0.637, 1.006	0.058	
	High school	1.028	0.999, 1.058	0.063	**0.034**
	Graduate	1.006	0.992, 1.020	0.413	**0.050**

Notes. e^b = antilogarithm of regression coefficient corresponding to 100 m increment in distance; CI = confidence intervals; * significant education moderating effect. All regression coefficients are adjusted for respondents' age, gender, marital status, education, employment status and administrative-unit (neighbourhood) socio-economic status.

Supplementary Table 2: Associations of distance to park with non-zero weekly minutes of non-walking leisure time physical activity by employment status and city in men

City	Employment status	e^b	95% CI	p-value	p-value of interaction
Curitiba (BR)*	Not working	**0.818**	**0.690, 0.969**	**0.020**	**0.049**
	Working	0.978	0.927, 1.033	0.422	
Olomouc (CZ)	Not working	1.042	0.931, 1.165	0.476	0.350
	Working	0.983	0.938, 1.030	0.474	
Aarhus (DK)	Not working	**0.909**	**0.831, 0.994**	**0.036**	0.206
	Working	0.967	0.930, 1.007	0.102	
North Shore (NZ)	Not working	1.048	0.855, 1.286	0.650	0.491
	Working	0.968	0.874, 1.071	0.527	
Waitakere (NZ)	Not working	1.046	0.903, 1.212	0.549	0.458
	Working	0.987	0.940, 1.036	0.585	
Wellington (NZ)	Not working	1.085	0.919, 1.282	0.335	0.176
	Working	0.960	0.901, 1.022	0.209	
Christchurch (NZ)	Not working	1.030	0.886, 1.196	0.702	0.495
	Working	0.971	0.899, 1.049	0.461	
Stoke-on-Trent (UK)	Not working	1.036	0.931, 1.154	0.514	0.975
	Working	1.035	0.977, 1.095	0.242	
Seattle (US)	Not working	1.026	0.943, 1.116	0.557	0.525
	Working	0.997	0.972, 1.023	0.813	
Baltimore (US)*	Not working	**1.049**	**1.002, 1.098**	**0.041**	**0.008**
	Working	0.982	0.965, 1.000	0.056	

Notes. e^b = antilogarithm of regression coefficient corresponding to 100 m increment in distance; CI = confidence intervals; * significant employment status moderating effect. All regression coefficients are adjusted for respondents' age, gender, marital status, education, employment status and administrative-unit (neighbourhood) socio-economic status.

Supplementary Table 3: Associations of distance to park with non-zero weekly minutes of non-walking leisure time physical activity by employment status and city in women

City	Employment status	e^b	95% CI	p-value	p-value of interaction
Curitiba (BR)	Not working	0.982	0.898, 1.073	0.688	0.583
	Working	1.015	0.937, 1.099	0.713	
Olomouc (CZ)	Not working	1.029	0.923, 1.148	0.606	0.642
	Working	1.001	0.956, 1.047	0.976	
Aarhus (DK)	Not working	0.980	0.918, 1.044	0.527	0.819
	Working	0.971	0.937, 1.006	0.109	
North Shore (NZ)	Not working	0.908	0.793, 1.041	0.166	0.185
	Working	1.011	0.930, 1.099	0.803	
Waitakere (NZ)*	Not working	1.105	0.997, 1.225	0.057	**0.020**
	Working	0.968	0.926, 1.012	0.154	
Wellington (NZ)	Not working	1.022	0.884, 1.180	0.770	0.569
	Working	0.977	0.921, 1.036	0.437	
Christchurch (NZ)	Not working	0.961	0.856, 1.080	0.506	0.841
	Working	0.948	0.876, 1.026	0.183	
Stoke-on-Trent (UK)	Not working	0.929	0.857, 1.006	0.072	0.258
	Working	0.979	0.934, 1.026	0.372	
Seattle (US)*	Not working	**0.953**	**0.908, 0.999**	**0.049**	**0.019**
	Working	1.018	0.988, 1.048	0.241	
Baltimore (US)	Not working	**1.038**	**1.000, 1.078**	**0.048**	0.259
	Working	1.014	0.995, 1.033	0.148	

Notes. e^b = antilogarithm of regression coefficient corresponding to 100 m increment in distance; CI = confidence intervals; * significant employment status moderating effect. All regression coefficients are adjusted for respondents' age, gender, marital status, education, employment status and administrative-unit (neighbourhood) socio-economic status.