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Access to parks and physical activity: an eight country comparison

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Abstract

Several systematic reviews have reported mixed associations between access to parks and physical activity, and suggest that this is due to inconsistencies in the study methods or differences across countries. An international study using consistent methods is needed to investigate the association between access to parks and physical activity.

The International Physical Activity and Environment Network (IPEN) Adult Study is a multi-country cross-sectional study using a common design and consistent methods. Accelerometer, survey and Geographic Information Systems (GIS) data for 6,181 participants from 12 cities in 8 countries (Belgium, Brazil, Czech Republic, Denmark, Mexico, New Zealand, UK, USA) were used to estimate the strength and shape of associations of 11 measures of park access (1 perceived and 10 GIS-based measures) with accelerometer-based moderate-to-vigorous physical activity (MVPA) and four types of self-reported leisure-time physical activity. Associations were estimated using generalized additive mixed models.

More parks within 1km from participants' homes were associated with greater leisure-time physical activity and accelerometer-measured MVPA. Respondents who lived in the neighborhoods with the most parks did on average 24 minutes more MVPA per week than those living in the neighborhoods with the lowest number of parks. Perceived proximity to a park was positively associated with multiple leisure-time physical activity outcomes. Associations were homogeneous across all cities studied.

Living in neighborhoods with many parks could contribute with up to 1/6 of the recommended weekly Having multiple parks nearby was the strongest positive correlate of PA. To increase comparability and validity of park access measures, we recommend that researchers, planners and policy makers use the number of parks within 1km travel distance of homes as an objective indicator for park access in relation to physical activity.

Key words: IPEN, accelerometry, GIS, leisure-time, exercise, multi-country, recreation

Introduction

Sufficient regular physical activity, at least 150 minutes of moderate-intensity aerobic physical activity throughout the week as recommended by the World Health Organization (WHO, 2010), reduces the risk of non-communicable diseases such as type 2 diabetes, coronary heart disease, hypertension, depression, and breast and colon cancers, and increases life expectancy (Lee et al., 2012). Worldwide, 23.3% of adults (15 years and older) are not sufficiently active (Sallis et al., 2016a), with proportions ranging from 15% in southeast Asia to about 32% in the Americas and the eastern Mediterranean (WHO, 2014).

Different domains of physical activity, such as leisure and active transportation, are influenced by many factors, and ecological models of behavior (Sallis et al., 2006) have frequently been used in designing studies to understand these multiple influences. Within several fields there has been considerable interest in possible associations between physical activity and presence or access to parks and other urban green spaces. Having parks in their neighborhood provides residents with the space or facilities for physical activity, which is one of the mechanisms that could explain observed associations between residential green space and better health outcomes (Dadvand et al., 2016; Hartig et al., 2014; Sugiyama et al., 2008).

Positive associations between various types of physical activity have been reported for perceived distance to the nearest park (Jáuregui et al., 2016a;Toftager et al., 2011; Schipperijn et al., 2010), amount of green space close to home (Kaczynski et al., 2009; Kaczynski et al., 2014), size of the nearest park (Giles-Corti et al., 2005; Kaczynski et al., 2008; Schipperijn et al., 2013), number of nearby parks (Cohen et al., 2006; Kaczynski et al., 2009; Kaczynski et al., 2014), and presence of certain park features such as walking paths and sports facilities (Kaczynski et al., 2008; Schipperijn et al., 2013).

However, reviews by Ekkel and De Vries (2017), Lachowycz and Jones (2011), and Kaczynski and Henderson (2007) showed the evidence for a positive relation between parks and physical activity as well as other health related outcomes was inconclusive, and results were difficult to compare directly because of the wide range of measures and methods used to determine park access and physical activity. The review by Lachowycz and Jones (2011) reported inconclusive results when comparing findings from studies conducted in different countries and continents. For example, of the 13 reviewed studies conducted in Europe, six did not find a significant association between parks and physical activity, three found a positive association, and four found mixed associations. All three review papers argued for more comparable measures to be used. A recent paper based on a European WHO workshop recommended using a 300 meter (m) maximum Euclidian distance to the boundary of urban green spaces of a minimum size of 1 hectare, when estimating the accessibility of urban green space (Annerstedt van den Bosch et al., 2016). This recommendation has, however, already been criticized in the review by Ekkel and De Vries (2017) as the evidence for this recommendation was limited.

The International Physical Activity and the Environment Network (IPEN) Adult Study (Sallis et al., 2016b; Kerr et al., 2013), provides a unique opportunity to analyze comparable cross-country data on both parks and physical activity. The main aim of the present paper was to estimate the strength and shape of associations of perceived proximity to parks and a number of Geographic Information Systems (GIS) based park access measures with accelerometer-based overall moderate-to-vigorous physical activity (MVPA) and multiple domains of self-reported leisure-time physical activity (LTPA).

Methods

Study design and neighborhood selection

The methods for the IPEN Adult Study have been described in detail elsewhere (Kerr et al., 2013). IPEN Adult is a multi-country cross-sectional study using a common design and consistent methods and included participants from 17 cities in 12 countries: Australia (Adelaide, AUS), Belgium (Ghent, BEL), Brazil (Curitiba, BRA), Colombia (Bogota, COL), Czech Republic (Olomouc and Hradec Kralove, CZ), Denmark (Aarhus, DEN), Hong Kong/China (HK), Mexico (Cuernavaca, MEX), New Zealand (North Shore, Waitakere, Wellington, and Christchurch, NZ), Spain (Pamplona, SP), the United Kingdom (Stoke-on-Trent, UK), and the United States of America (Seattle/King County, Washington and Baltimore, Maryland region, USA). To maximize variance in neighborhood walkability (a construct that indicates how conducive for utilitarian walking a neighborhood is, with components including residential density and mixed land use; Frank et al., 2010) and socioeconomic status (SES), IPEN study procedures involved identifying similar neighborhoods across cities stratified as follows: higher walkable/higher SES, higher walkable/lower SES, lower walkable/higher SES, and lower walkable/lower SES. Using GIS, neighborhood walkability index scores (Adams et al., 2014; Frank et al., 2010) were created for small geographic areas (neighborhoods) in each city. The neighborhoods were delineated based on the locally available "administrative units" that were more or less equivalent to US Census block groups, with between 500 and 3000 inhabitants. Neighborhoods that met criteria for the four strata were selected in each city, and participants were recruited in a balanced fashion from each neighborhood to control for seasonal effects and other confounders.

Participant recruitment

In the selected neighborhoods, households were randomly identified using databases from commercial and government sources. One adult in each selected household was asked to complete a survey and wear an accelerometer to objectively measure physical activity. All participants provided informed consent, and ethical approval was obtained from local institutional review boards in each country. The data collection dates ranged across cities from 2002 to 2011.

Participants

The IPEN Adult study comprised 14,222 adults aged 18-66 years from 17 cities in 12 countries. Five out of 17 study sites did not collect objective physical activity data, relevant GIS data and/or self-reported LTPA data (Adelaide, AUS; Bogotá, COL; Hradec Kralove, CZ; Hong Kong, HK; Pamplona, SP). Of 8,568 participants from the remaining 12 cities in 8 countries (Ghent, BEL; Curitiba, BRA; Olomouc, CZ; Aarhus, DEN; Cuernavaca, MEX; North Shore, Waitakere, Wellington, and Christchurch, NZ; Stoke-on-Trent, UK; Seattle/King County, Washington and Baltimore, Maryland region, USA), 1,808 did not wear an accelerometer because they did not consent to this part of the study or were not asked to do so. To be included in the current study, participants needed to have accelerometer data for at least 10 hours per day, for at least four days. They furthermore needed to have valid GIS data and complete survey data for all relevant variables. The socio-demographic characteristics of the final sample used in this paper (N=6,181) with valid accelerometer, GIS, and survey data by study site are presented in Table 1.

When compared to participants who did not wear accelerometers or had fewer than four valid days of accelerometer data, those who had at least four valid days with sufficient wear-time were more likely to be older (p<.001), married or in a de facto relationship (p=.005), employed (p=.012), hold a tertiary degree (p<.001) and live in higher income areas (p=.002).

[insert table 1 around here]

Outcome measures

A recent study based on IPEN Adult data has shown that self-reported and objectively measured physical activity essentially are two different constructs and that the correlation between the two is limited (Cerin et al., 2016). Accelerometers give an accurate measure of overall MVPA, but they cannot reveal in which domain the activities are undertaken in (work, leisure, transport). For that reason, we chose to use objectively measured overall MVPA as the main outcome, supplemented by self-reported measures that shed light on the particular behaviors of 'leisure-time walking' (LTW) and 'moderate- to vigorous-intensity leisure-time physical activity other than walking' ('other LTPA'). These subjective measures are hypothesized to be closely correlated to the presence of parks.

The mean daily minutes spent in MVPA was assessed by asking participants to wear accelerometers on their hip for 7 days, except during sleep, swimming, and showering. Countries used varying models of ActiGraph monitors (Pensacola, FL), except for New Zealand that used Actical devices (Philips Respironics). Only vertical axis data, expressed as counts per minute (cpm), were used. Data were collected using 60-second epochs, and non-wear time was defined as >60 consecutive minutes with zero cpm. A day had to have at least 10 hours of wear time to be considered valid, and participants with at least 4 valid days were included in analyses. For the ActiGraph data, Freedson's (1998) cutpoint of ≥1952 cpm was used to derive mean minutes of MVPA per valid day. To enable comparison with the ActiGraph, a new cut-point estimate for MVPA (≥ 730 cpm) was developed for the Actical data (Cain 2013). All accelerometer data were scored with MeterPlus version 4.3 (www.meterplussoftware.com).

Leisure time specific items from the International Physical Activity Questionnaire – Long Form (IPAQ-LF) were used to assess LTW and 'other LTPA'. In an international study, the IPAQ-LF was shown to be similarly reliable and valid to other self-report measures (Craig et al., 2003). Participants were asked to report the number of days and usual daily minutes spent in ≥10min bouts on each of these two leisure activities in the last week. Dichotomous outcome measures were computed to represent any ≥10min-bout of LTW and other LTPA, during the last week (no=0, yes=1, where yes implies non-zero min/week). Also, for the participants engaging in any LTW or other LTPA the total weekly minutes (days times min/day) were treated as separate continuous variables.

Park access measures

As mentioned in the introduction, a wide range of park access measures has been used in previous studies, and it is unclear which measure would be the most appropriate correlate of physical activity. We therefore used the 11 different park access measures (one perceived and 10 objective) that were available in the IPEN data set. All 11 measures have been used in other studies, but to our knowledge, never all in one study. Table 2 shows the descriptive statistics for all 11 measures for all 12 study cities.

[insert table 2 around here]

Perceived proximity to a park

Perceived proximity to a park was assessed by a single item from the Neighborhood Environment Walkability Scale (NEWS, Cerin et al., 2009; Adams et al., 2009) survey by asking respondents to categorize the time it took to walk to their nearest park on a 5-point scale (1= more than 30 min, 2 = 21-30 min, 3 = 11-20, 4= min 6-10 min, and 5 = 1–5 min). The NEWS has substantial evidence of test-retest reliability and construct validity (Brownson et al., 2009; Cerin et al., 2008; Saelens et al., 2003).

Objectively measured access to parks

IPEN project teams in participating countries used ArcGIS software to geocode participant residences, create 1-kilometer (km) and 500-meter street-network buffers around the home address for each participant, and create park access measures (Adams et al., 2014). Street-network distances provide a better representation of the experienced distance than Euclidian distances. The IPEN study coordinating center developed a set of GIS templates to guide countries to a common definition of public parks and then evaluated comparability of resulting park measures across countries (Adams et al., 2014). A park was defined in these templates as a government designated park of any size that was free and open to the public and maintained by a government agency. Parks could be unimproved (e.g. woodland or grassland) or have improved features (e.g. with sports, play or recreation facilities). We examined 10 objective measures of park access:

Number of parks contained within or intersected by 1km or 500m street-network buffers was calculated by attributing park polygons to a buffer if any portion of the park was contained within or intersected with the buffers around each home address for each participant in each city.

Total park area contained within or intersected by 1km or 500m buffers was calculated by summing the total land area of park polygons (in acres) contained within or intersected by the buffers around each participant's home address.

Distance to the nearest park, irrespective of size, was calculated using the street network distance from each participant’s home address to the nearest park using the network analyst extension in the ESRI ArcGIS software. Determining distances in this way requires an origin point and a destination point, both of which need to be located on the walkable road network. The participant’s home address was used as the origin point. Destination points representing parks were created at the locations where the park polygon (defined using a 50-foot buffer around the park) intersected with the road network. This method typically resulted in multiple points for a single park and all points were accepted as representative of where someone could enter the park.

Distance to the nearest parks of specific sizes was calculated in the same way for parks in five size categories (i.e., ≤1 acre, >1 to ≤5 acres, >5 to ≤10 acres, >10 acres to ≤50 acres, >50 acres. 1 acre = 4,047 square meters). Parks of >50 acres were not present in Olomouc (CZ). Four participants from Olomouc did not have access to parks of some size categories via the street network. These missing data on distance to parks of specific sizes due to unavailability/inaccessibility were replaced with maximal observed distance values to parks (10km).

Covariates

The following covariates were included in analyses: age, gender, education (<12 yrs of high school, high school degree, university degree), marital status (married/living with partner vs. other), employment status (unemployed vs. employed), city, accelerometer wear time, and administrative-unit-level SES (low vs. high). The covariates were selected based on a priori knowledge from previous studies in this field or in relation to the sampling procedure and study design we used.

Data Analytic Plan

Descriptive statistics were computed for the whole sample with valid data and by city. Associations of environmental variables with physical activity were estimated using generalized additive mixed models (GAMMs) (Cerin et al., 2014). GAMMs can accommodate positively skewed and categorical outcomes, account for dependency in error terms due to clustering (i.e., participants recruited from selected administrative units), and estimate complex dose-response relationships (Wood, 2006). GAMMs with binomial variance and logit link functions were estimated for any ≥10min bouts of leisure-time walking and other LTPA in the last week (dichotomous outcomes). The antilogarithms of the regression coefficient estimates of these GAMMs represent odds ratios. We used GAMMs with Gamma variance and logarithmic link function to model total weekly minutes of leisure-time walking and other LTPA (continuous outcomes) in those that reported any ≥10min bouts (i.e., those with non-zero min/week) of walking or other LTPA, respectively, and to model average daily minutes of objectively-assessed MVPA. The antilogarithms of these regression coefficient estimates represent the proportional difference in outcomes associated with a unit difference in the correlates. For all GAMMs, random intercepts were specified to account for clustering effects at the administrative unit level.

Main-effect single-park-access-variable GAMMs estimated the dose-response relationships of all park access measures with each physical activity outcome, adjusting for city, socio-demographic covariates, administrative-unit-level SES, and accelerometer wear time variables, as appropriate (hereafter named 'covariates'). Curvilinear relationships of park access measures with outcomes were estimated using thin-plate spline smooth terms in GAMMs (Wood, 2006). Smooth terms failing to provide sufficient evidence of a curvilinear relationship (≥10 difference in Akaike Information Criterion - AIC, Burnham & Anderson, 2002) were replaced by simpler linear terms. Separate GAMMs were run to estimate park access by city interaction effects to test for heterogeneity in associations across cities. The significance of interaction effects was evaluated by comparing AIC values of models with and without a specific interaction term (≥10 difference in AIC, Burnham & Anderson, 2002). Significant interaction effects were probed by computing city-specific associations.

For each of the five physical activity outcomes (4 self-reported and 1 objective), we also estimated GAMMs including multiple park access correlates independently contributing to the explanation of a specific outcome (named park-access-multivariable models). For these models, objective measures of access to parks that were significant in the single-park-access-variable models (including interaction terms) were entered in the GAMMs first, followed by perceived access to parks (if appropriate). This was done because the associations of objective measures of park access may be mediated by perceived park access (Jáuregui et al., 2016b; Gebel et al., 2011). Only park access correlates that were statistically significant were retained in these models. Multiple park access variables could be simultaneously entered in GAMMs as collinearity was not a problem (variance inflation factor<2). All analyses were conducted in R (R Core Team, 2015) using the packages 'mgcv' (Wood, 2006) and 'car' (Fox & Weisberg, 2011).

Results

Patterns of park access and physical activity

Tables 1 and 2 show the overall and city-specific descriptive statistics for physical activity outcomes and park access measures, respectively. Cities in the Americas had lower average levels of objectively-assessed MVPA as compared to the European and New Zealand cities (Table 1). The highest levels of leisure-time walking (prevalence and min/week) were observed in Olomouc (CZ) and Aarhus (DEN), and the lowest levels in Curitiba (BRA) and Cuernavaca (MEX). Aarhus (DEN) had also the highest self-reported levels of other LTPA, and with Curitiba (BRA), Cuernavaca (MEX) and Stoke-on-Trent substantially below average.

With respect to park access measures, Curitiba (BRA), Aarhus (DEN), and the New Zealand cities had the highest level of perceived proximity to a park, while Ghent (BEL), Cuernavaca (MEX) and Olomouc (CZ) had the lowest (Table 2). The number of parks contained within or intersected by 1km or 500m buffers showed considerable differences between countries as well, with Cuernavaca (MEX) having the lowest number of parks and North Shore (NZ) the highest. The area of parks contained within or intersected by 1km or 500m buffers showed large differences with an overall median of 25.2 acres (101,981 square meters) within 1km across all cities, but the median values ranged from 0.9 acres (3,642 square meters) in Cuernavaca (MEX) to 61.5 acres (248,882 square meters) in Aarhus (DEN). The mean values differed even more, showing a skewed distribution within cities (data not shown). Also, the objectively measured distances to the nearest park showed large differences between the cities, both for parks of any size, and for parks in the different size categories.

Associations of park access measures with physical activity

Single-park-access variable models indicated that perceived proximity to a park and number of parks contained within or intersected by 1km buffers were the two environmental variables with the most consistent associations with physical activity outcomes (Table 3; Figures 1-3). Specifically, perceived proximity to a park was positively related with average daily minutes of objectively-assessed MVPA (Figure 1), with the odds of engaging in leisure-time walking (Figure 2), and with other LTPA (Figure 3). More parks within a 1km buffer was predictive of more objectively-assessed MVPA (Figure 1), more weekly minutes of leisure-time walking (Figure 2) and other LTPA among those who engaged in these types of activities (Figure 3), and higher probability of engaging in leisure-time walking (Figure 2). The number of parks within a 500m buffer was also significantly related to objectively-assessed MVPA, although this positive association was weak. No significant associations were found between the two park area measures and any of the five physical activity outcomes.

The objectively measured distance to the nearest park of any size showed an inverse association with the odds of engaging in leisure-time walking (Table 3; Figure 2), indicating that the odds of walking decreased with increasing distance from parks. Negative associations were also observed for distance to the nearest ≤ 1-acre park with objectively-assessed daily minutes of MVPA (Figure 1) and the odds of engaging in leisure-time walking (Figure 2). Finally, a negative, but weaker association was found between distance to the nearest >50 acres park and weekly minutes of leisure-time walking in those who engaged in this type of activity (Figure 2).

No evidence of non-linearity of associations was found. Associations were homogeneous across all cities with the exception of those linking perceived proximity to a park with non-zero weekly minutes of leisure-time walking and other LTPA. Positive associations were found with the former physical activity outcome only in Ghent, Belgium (e^b = 1.074, 95% CI = 1.008, 1.146; p = .027), Olomouc, Czech Republic (e^b = 1.146, 95% CI = 1.001, 1.314; p = .049), and North Shore, New Zealand (e^b = 1.252, 95% CI = 1.061, 1.478; p =

.008). Non-zero weekly minutes of other LPTA were positively related to perceived proximity to parks only in Cuernavaca, Mexico ($e^b = 1.121$, 95% CI = 1.020, 1.231; p = .017).

Both perceived proximity to parks ($e^b = 1.088$, 95% CI = 1.035, 1.144; p = .001) and objectively-assessed distance to nearest ≤1 acre parks ($e^b = 0.995$, 95% CI = 0.990, 0.999; p = .030) were independently significantly associated with the odds of engaging in ≥10 min/wk of leisure-time walking. The number of parks contained or intersected by 1km buffers ($e^b = 1.013$, 95% CI = 1.001, 1.025; p = .035) and perceived proximity to parks were significant correlates of non-zero weekly minutes of leisure-time walking. Yet, the latter measure of access to parks was a significant correlate only in Olomouc, Czech Republic ($e^b = 1.142$, 95% CI = 1.001, 1.312; p = .049) and North Shore, New Zealand ($e^b = 1.213$, 95% CI = 1.027, 1.433; p = .023).

Discussion

Of the 11 measures of park access examined, the objectively-assessed *number of parks within a kilometer from home using the street-network* and the *perceived proximity to a park* showed the most consistent positive associations with the five physical activity outcomes. In other words, having more parks within 1km of participants' homes was associated with more reported leisure-time physical activity and more objectively measured MVPA. The perception of having a park close by was also positively associated with multiple physical activity outcomes.

For the seven park distance measures, associations were mixed, and only three of 35 possible associations were significant. We did not find associations between park area close to home and any of the five physical activity outcomes.

With the exception of the association between perceived proximity to a park and non-zero weekly minutes of leisure-time walking and other LTPA, none of the observed associations differed across the 12 cities included in our study, indicating the findings are robust and valid across a wide range of urban environments and cultures. It would be reasonable to expect an s-shaped relation for some park access measures indicating both a lower threshold below which differences would not be visible as well as a leveling off of differences at higher levels. However, no evidence of non-linearity of associations was found, so living near more parks was linearly related to more reported and objectively-measured physical activity.

As noted, the number of parks within the 1km buffer had the strongest and most consistent associations, with significant findings for 3 of 5 physical activity measures. The fact that the number of parks close by is related to various types of physical activity confirms similar results from earlier studies (e.g. Cohen et al., 2006; Kaczynski et al., 2009; Kaczynski et al., 2014, Kaczynski et al., 2016). Our study showed the relation to be linear and present in multiple cities across different countries and cultures. On average, each additional park within 1km was associated with 1.8 more minutes of weekly MVPA. Respondents who lived in the neighborhoods with the most parks accumulated on average 24 minutes more MVPA per week than those living in the neighborhoods with the lowest number of parks.

The observation that total park area did not show an association, whereas the number of parks did, indicated that having a greater number of parks close by is more important for physical activity than having a large park area close by. Having multiple parks relatively close by most likely gives people access to parks that vary by the types of activities supported and characteristics of the people who go there which probably increases the possibility that people can find the ‘right’ park that suits their preferences and provides opportunities for their preferred activities. Ekkel and De Vries (2017) argued that the cumulative opportunities to access a park and engage in desired activities are of greater importance than the distance to a park, which seems to be supported by our results.

The current study did not measure activity opportunities or features within parks, but other studies have found that the number of activity opportunities in a park, the perceived quality, and the presence of specific features, such as walking trails, have been associated with more physical activity (e.g., Kaczynski et al., 2008; Schipperijn et al., 2013, Lindberg & Schipperijn, 2015). One study found that having an attractive (but not necessarily large) green space nearby was positively related to any recreational walking, and having a large attractive (but not necessarily close) green space may help adult residents achieve sufficient amounts of physical activity through recreational walking (Sugiyama et al., 2010). Kaczynski and colleagues (2016) developed a ParkIndex measure that incorporates both the cumulative effect of having multiple parks nearby and the difference in opportunity and quality in each park, which will allow researchers, planners, and citizens to evaluate the potential for park use for a given area.

With regards to distance to the nearest park, the results from our study showed a clear difference between the objective distance measures and the perceived distance to the nearest park. For the objective measures only three out of 35 possible associations were significant, and not always in the expected direction, whereas perceived access to a park was positively related to four of the five physical activity measures. Other studies that included both type of measures had similar findings (e.g. Schipperijn et al., 2013; McCormack, Cerin, Leslie, Du Toit, & Owen, 2008; Schipperijn et al., 2010b; Scott et al., 2007). A possible explanation for the more consistent relation with perceived proximity might lie in differences in park definitions. What is defined, as a park by a local authority might not always be perceived as a park by inhabitants. Our definition of a park was quite broad. Parks could include unimproved spaces and those including improved features could vary greatly in terms of type, quality and features present. It could be hypothesized that respondents in a survey think about a park they use when asked to rate the distance to the closest park from their home. They may ‘overlook’ a park that is closer but that they do not use, or parks they are not aware of. It seems that asking respondents about the distance to their nearest park is a conceptually different measure of park access than objectively measuring the distance from their home to the nearest park. The two measures are related, but not the same, which is consistent with the poor agreement between perceived and objectively measured distance to parks reported elsewhere (e.g. Adams et al., 2014; Lackey & Kaczynski, 2009). In a recent Australian study by Wang et al (2015), the most important factors influencing perceived accessibility to urban parks were physical and locational features such as proximity to the park, a pleasant walking experience, and a sufficient number of parks in the neighborhood. In a Mexican study, the relation between MVPA and perceived-park access was moderated by the perception of safety from crime – with parks being positively related to MVPA levels only among those that perceived them as being safe from crime (Salvo et al., 2014).

Present results indicated that objectively estimating the distance to the nearest park from home was not the most suitable indicator when trying to investigate the relation between park access and physical activity. Fortunately for planners and policy makers, the number of nearby parks, which is an objective metric that can be relatively easily calculated, did show a positive relation with various physical activity outcomes.

The fact that there were considerable differences in the provision of green space among the 12 study sites, but there was little variation between sites in the associations, indicates the reported associations would likely be relevant in many countries. Thus, this international study provided robust evidence that living nearby multiple parks is a generalizable correlate of physical activity across countries.

Strengths and weaknesses

The main strengths of the present study were the large sample, consistent design and measures, wide range of 12 urban environments from eight middle- and high-income countries across the world, comprehensive analytical approach, and use of objective as well as self-reported measures for both independent and dependent variables.

As this was a cross-sectional study, it is not possible to draw conclusions on causality from our findings. It is possible that the associations observed could be explained by other factors that were not measured. As with all self-reported data, there is a risk of self-report bias. Although the countries in the study represented a range of cultures, income levels, and built environments, no low-income countries were included. Thus, future studies should also include low-income countries, when possible. Even though the sampling of participants was carefully balanced between different SES groups, as well as neighborhood walkability, some response bias was documented. Although consistent objective GIS measures of the environment have many benefits, these measures do not provide information on the quality, safety, cleanliness, or aesthetic features of a park, which are highly likely to influence park use by neighborhood residents (e.g., Rung et al., 2011; Schipperijn et al., 2013; Ekkel and De Vries, 2017). The GIS measured used in this study did not include the number or type of features that were present in each park, and adding this information is recommendable for future studies. It would be valuable for future studies to explore potential mechanisms by which multiple nearby parks might promote more total physical activity. Other authors have proposed various explanations that could be tested, including multiple parks might simply provide more options for physical activity, might create a more pleasant neighborhood that encourages physical activity in or out of parks, or might serve as a psychological cue that physical activity is valued or recommended (see Kremers et al 2006).

Implications

The results from this study demonstrated the importance of having multiple parks within walking distance from home as a support for LTPA and overall MVPA. Respondents living near the most parks accumulated on average 24 minutes of objectively-measured MVPA more per week compared to those living near the fewest parks. Parks were similarly related to physical activity in a wide range of middle- and high-income countries, indicating that the role of multiple nearby parks for adult physical activity is a broadly generalizable principle. The self-report and GIS measures of park access used in the present study are feasible for use in many countries. We encourage researchers, practitioners, and government agencies in public health and park and recreation fields, among others, to incorporate these or similar measures in their work. The descriptive data from the 12 cities in the present study can assist in interpreting park proximity and density data in other locations, if comparable measures are used.

To increase comparability and validity of park access measures, we recommend that researchers, planners and policy makers use the number of parks within 1km from residential addresses as the preferred objective indicator for park access in relation to adults' physical activity. In the future, a park access measure that incorporates the cumulative opportunities and qualities of nearby parks might be an even more powerful indicator of the impact of parks on physical activity and health.

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Figure 1: Associations of measures of park access with objectively measured moderate-to-vigorous physical activity (single environmental variable models). The solid line is visualizing the association and the dotted lines represent the 95% CI

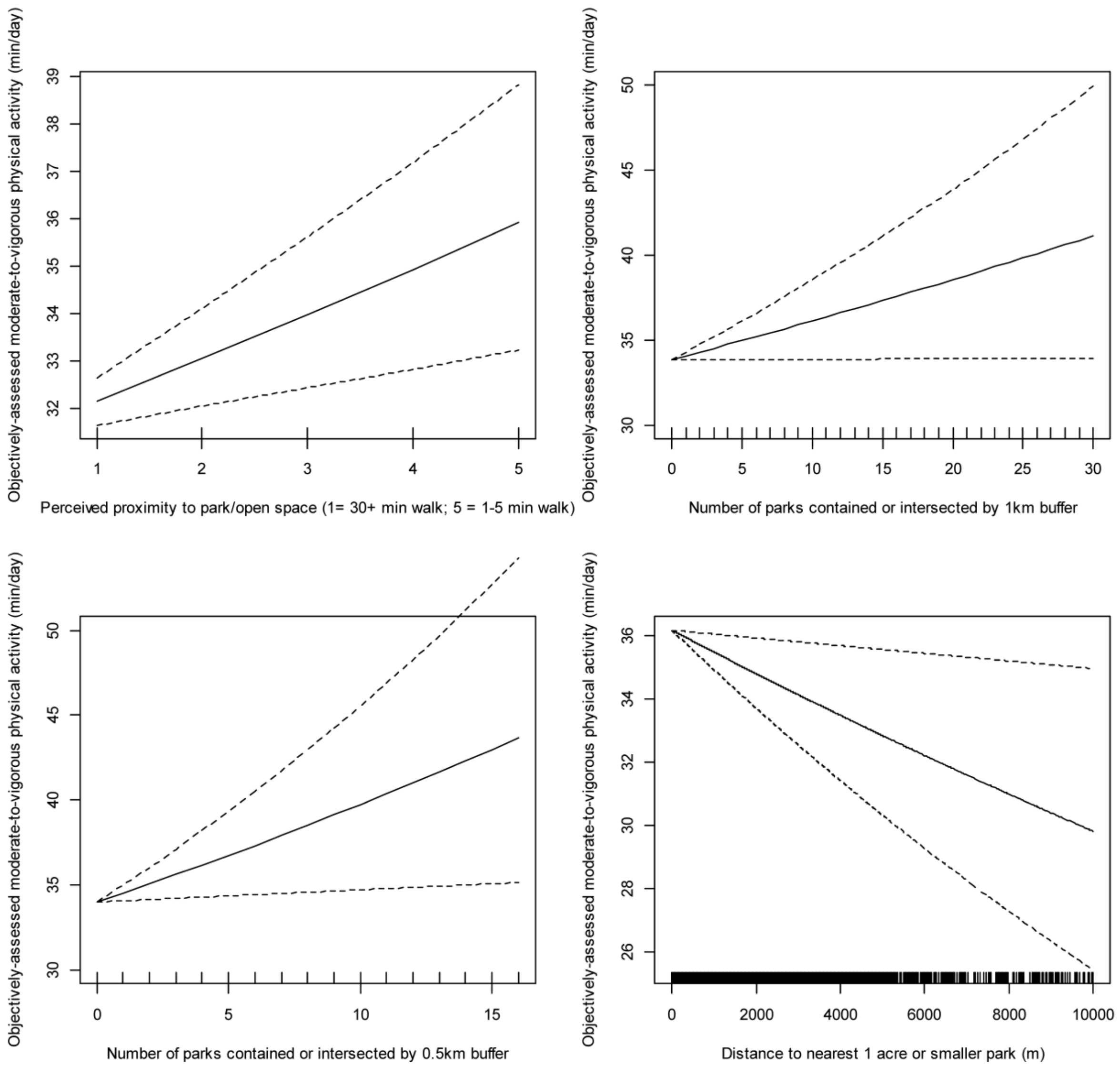

Figure 2: Associations of measures of park access with leisure-time walking (single environmental variable models). The solid line is visualizing the association and the dotted lines represent the 95% CI

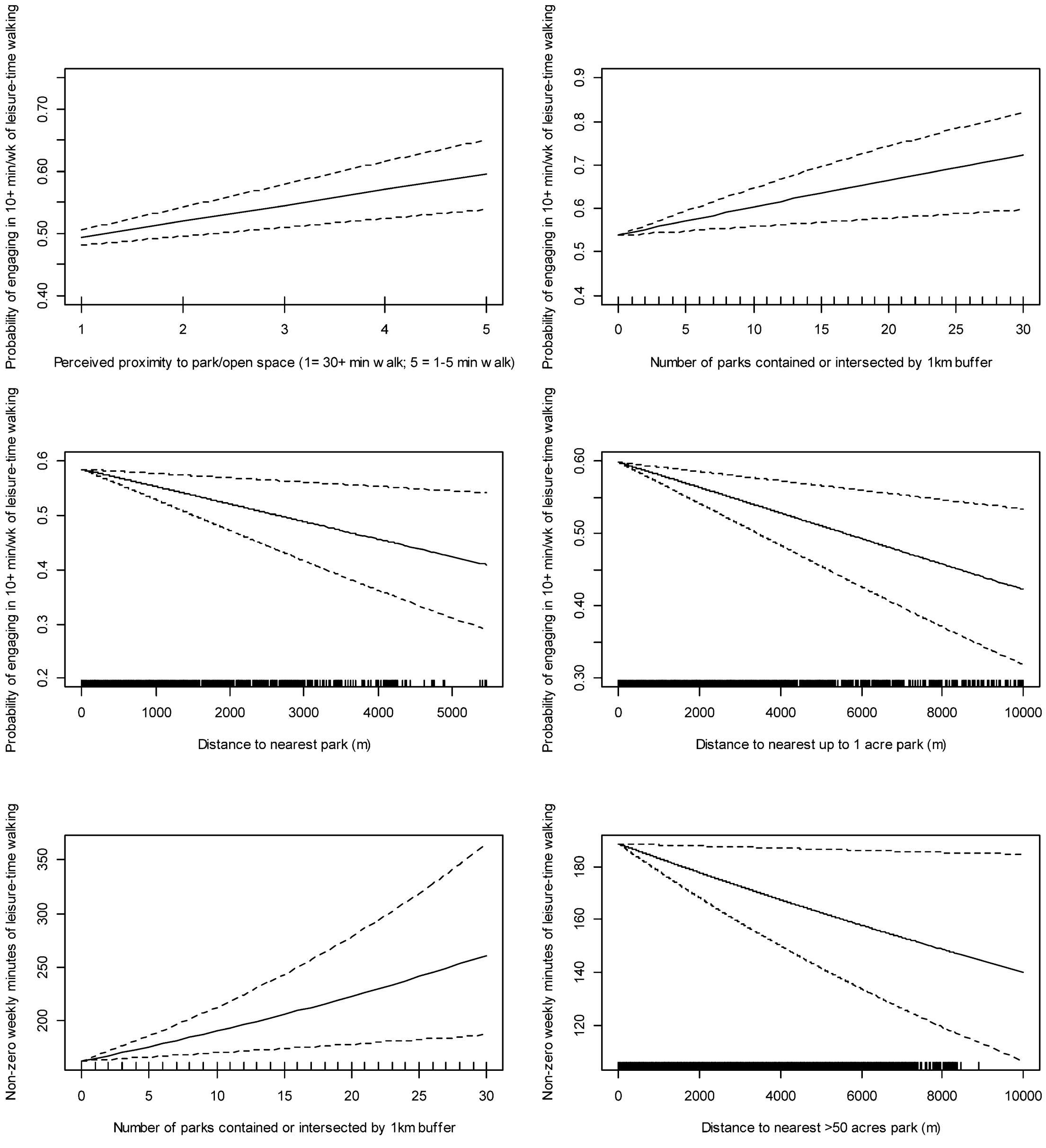

Figure 3: Associations of measures of park access with other leisure-time physical activity (single environmental variable models). The solid line is visualizing the association and the dotted lines represent the 95% CI

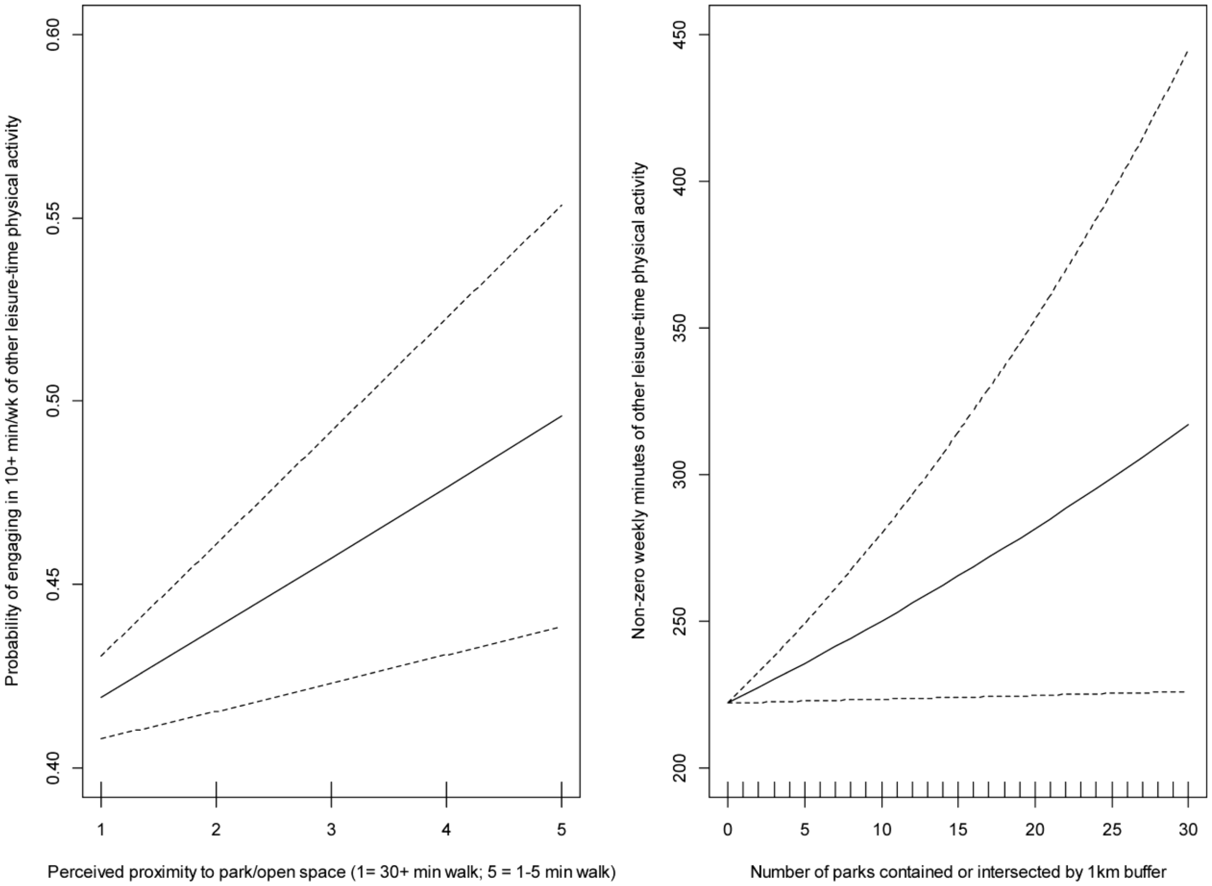

Table 1: Descriptive statistics of sample socio-demographic characteristics and physical activity measures (N=6,181)

	All Cities	BEL[1]	BRA[2]	CZ[1]	DEN[2]	MEX[1]	NZ				UK[2]	USA	
Socio-demographics							North Shore[1]	Waitakere[1]	Wellington[1]	Christchurch[1]		Seattle	Baltimore
N	6,181	1,027	328	212	267	631	358	398	414	363	125	1194	864
Age, years *Mean (SD)*	43 (12)	43 (13)	42 (13)	38 (14)	40 (14)	42 (13)	43 (12)	42 (11)	40 (12)	43 (12)	44 (13)	44 (11)	47 (11)
Gender, *%men*	47.3	48.6	48.5	34.9	38.6	46.0	37.1	40.5	47.6	45.7	48.0	55.0	49.0
Education, *%*													
Less than HS	10.0	4.4	28.1	22.1	7.5	44.8	2.5	3.8	0.5	8.3	37.6	1.1	1.9
HS graduate	38.9	32.7	31.1	43.9	42.3	27.9	57.6	64.6	44.9	56.7	47.2	34.9	29.6
College or more	51.1	62.9	40.9	34.0	50.2	27.3	39.9	31.7	54.6	35.0	15.2	64.0	68.5
Work status, *%working*	80.5	80.9	79.3	76.4	75.7	72.3	77.1	86.2	87.4	86.0	64.4	81.3	83.1
Marital status, *%couple*	65.6	73.8	60.4	60.4	69.3	65.9	72.1	76.1	60.1	57.6	48.0	64.1	61.1
Accelerometer variables													

Valid days of accel wear time													
Mean (SD)	6.5 (1.1)	6.7 (1.1)	6.7 (0.9)	6.2 (1.1)	7.0 (0.7)	5.7 (1.0)	6.4 (1.3)	6.4 (1.3)	6.7 (1.3)	6.5 (1.3)	6.6 (1.0)	6.7 (0.8)	6.7 (1.2)
Accel wear time (hrs/day)													
Mean (SD)	14.4 (1.3)	14.7 (1.3)	14.0 (1.3)	13.9 (1.4)	14.9 (1.1)	14.0 (1.4)	14.2 (1.2)	14.1 (1.3)	14.0 (1.2)	14.0 (1.2)	14.6 (1.2)	14.7 (1.3)	14.8 (1.4)
MVPA (min/day)*													
Median (IQR)	31.6 (31.0)	31.1 (26.6)	25.2 (27.4)	45.9 (34.8)	34.9 (29.4)	24.8 (29.1)	41.8 (35.2)	31.4 (33.0)	44.9 (33.7)	37.9 (38.2)	32.0 (30.7)	31.0 (30.9)	23.9 (29.2)
Self-reported leisure-time physical activity (LTPA)													
≥10min/wk walking, %	55.9	48.6	35.7	69.3	79.8	33.0	57.8	55.8	68.4	49.3	48.8	65.9	61.8
Total min/wk walking[3]													
Median (IQR)	30 (120)	0 (120)	0 (60)	120 (355)	120 (280)	0 (60)	30 (120)	25 (120)	60 (135)	0 (120)	0 (150)	60 (140)	40 (135)
Non-zero min/wk walking[3]													
Median (IQR)	120 (165)	120 (120)	120 (140)	210 (300)	180 (340)	120 (150)	90 (135)	100 (135)	120 (150)	120 (150)	150 (340)	120 (165)	105 (150)
≥10min/wk other LTPA, %	48.0	50.1	35.1	52.8	77.9	35.2	45.0	46.7	58.2	45.7	29.6	51.2	45.0

Total min/wk other LTPA													
Median (IQR)	0 (150)	15 (120)	0 (100)	40 (195)	120 (330)	0 (90)	0 (120)	0 (120)	60 (240)	0 (128)	0 (60)	20 (180)	0 (150)
Non-zero min/wk other LTPA													
Mean (SD)	246 (256)	203 (236)	277 (307)	255 (258)	344 (356)	228 (230)	208 (193)	202 (239)	256 (230)	229 (214)	189 (140)	255 (267)	254 (252)
Median (IQR)	180 (210)	120 (180)	180 (270)	180 (220)	220 (320)	180 (240)	150 (180)	135 (180)	180 (260)	180 (215)	160 (150)	180 (230)	180 (250)

Notes: HS=high school; MVPA = moderate-to-vigorous physical activity; SD = standard deviation; IQR = interquartile range; valid days of accelerometer wear are those with 10+ valid hours of wear; accel = accelerometer; * = average for valid days.

[1] Study site aimed to collect accelerometer data in the total sample

[2] Study site aimed to collect accelerometer data in a fixed proportion of the total sample

[3] 13 values truncated at 1680 min/wk (4hr/day)

Table 2: Descriptive statistics of park access measures (N=6,181)

Park access measure (measurement unit)	All cities	BEL	BRA	CZ	DEN	MEX	NZ				UK	USA	
							North Shore	Waitakere	Wellington	Christchurch		Seattle	Baltimore
Perceived proximity to a park (5-point scale)													
Mean (SD)	3.9 (1.3)	3.1 (1.5)	4.7 (0.6)	3.4 (1.3)	4.6 (0.7)	3.2 (1.5)	4.5 (0.9)	4.4 (1.0)	4.5 (0.7)	4.6 (0.7)	3.5 (1.4)	4.0 (1.2)	3.9 (1.3)
Median (IQR)	4.0 (2.0)	3.0 (4.0)	5.0 (1.0)	3.0 (1.0)	5.0 (1.0)	3.0 (3.0)	5.0 (1.0)	5.0 (1.0)	5.0 (1.0)	5.0 (1.0)	4.0 (3.0)	4.0 (2.0)	4.0 (2.0)
No. parks of any size contained or intersected by 1km buffer													
Median (IQR)	3.0 (6.0)	3.0 (5.0)	5.0 (6.0)	2.0 (4.0)	4.0 (4.0)	1.0 (2.0)	10.0 (7.0)	8.0 (5.0)	4.0 (4.0)	6.0 (3.0)	2.0 (2.0)	3.0 (5.0)	2.0 (2.0)
No. parks of any size contained or intersected by 0.5km buffer													
Median (IQR)	1.0 (2.0)	1.0 (2.0)	1.0 (3.0)	1.0 (2.0)	1.0 (2.0)	0.0 (1.0)	4.0 (4.0)	3.0 (3.0)	1.0 (1.0)	1.0 (1.0)	1.0 (1.0)	1.0 (2.0)	1.0 (1.0)

Area of parks (any size) contained or intersected by 1km buffer (acres)													
Median (IQR)	25.2 (66.7)	21.8 (48.1)	9.0 (14.5)	6.9 (38.2)	61.5 (197.2)	0.9 (10.3	59.3 (105.7)	51.1 (65.3)	25.4 (78.8)	21.7 (67.6)	20.5 (35.6)	32.0 (56.0)	39.4 (203.2)
Area of parks (any size) contained or intersected by 0.5km buffer (acres)													
Median (IQR)	3.1 (17.0)	3.0 (10.2)	1.5 (7.1)	0.7 (6.1)	2.4 (9.5)	0.0 (0.9)	22.4 (27.1	14.8 (39.3)	3.9 (17.7)	1.3 (17.1)	4.1 (20.0)	4.9 (19.3)	2.7 (34.3)
Distance to nearest park of any size (100m)													
Median (IQR)	3.8 (4.8)	3.6 (6.3)	2.9 (4.2)	5.1 (4.6)	3.0 (3.1)	7.7 (10.3	1.7 (2.8)	3.8 (5.1)	3.5 (3.8)	2.8 (3.0)	3.1 (3.4)	3.9 (4.0)	4.5 (5.7)
Distance to nearest to ≤1 acre park (100m)													
Median (IQR)	9.5*(18.1)	28.5 (40.6)	4.6 (4.8)	11.7*(12.3)	6.1 (13.2)	14.9 (20.1)	2.9 (2.8)	6.0 (7.0)	6.7 (8.9)	4.4 (4.2)	16.1 (17.0)	12.5 (15.7)	19.8 (29.4)
Distance to nearest >1 to ≤5 acres park (100m)													
Median (IQR)	8.5*(12.4)	6.1 (31.6)	5.6 (6.2)	6.7*(6.6)	7.7 (10.6)	22.1 (26.2)	4.2 (4.6)	4.7 (3.9)	11.1 (6.1)	8.2 (6.0)	6.4 (10.0)	8.6 (10.8)	14.7 (22.9)
Distance to nearest >5 to ≤10 acres park (100m)													

Median (IQR)	12.9*(17.3)	10.2 (12.3)	21.6 (26.4)	19.4*(14.6)	9.6 (9.6)	31.4 (26.2)	8.1 (8.2)	11.1 (6.1)	11.9 (9.1)	14.6 (11.0)	10.3 (12.9)	10.7 (13.	24.4 (28.5
Distance to nearest >10 to ≤50 acres park (100m)													
Median (IQR)	10.7*(13.9)	9.1 (11.8)	54.2 (88.6)	14.8*(9.5)	13.7 (10.	43.9 (32.0)	5.8 (6.4)	6.9 (7.4)	10.7 (9.3)	9.1 (6.6)	11.1 (14.5)	7.3 (7.5)	15.0 (17.1
Distance to nearest >50 acres park (100m)													
Median (IQR)	20.8*(24.0)	43.3 (28.3)	38.0(38.6)	100.0*(0.0)	9.9 (12.0)	29.7 (25.0)	16.3 (11.7	18.3 (13.0)	14.1 (12.2)	17.7 (12.9)	26.0 (21.2)	17.5 (12.5)	16.7 (17.1

Notes: SD = standard deviation; IQR = interquartile range; * = missing data due to unavailability of such parks were replaced with maximal observed distance values to parks (i.e., 10,000 meters); for non-normally distributed variables only medians and IQR are reported.

Table 3: Pooled associations of park access measures with physical activity (PA) outcomes (single-environmental-variable models)

Park access measure	Engaging in ≥10 min/wk of leisure-time walking N=6181		Non-zero min/wk of leisure-time walking N=3417		Engaging in ≥10 min/wk of other leisure-time PA N=6181		Non-zero min/wk of other leisure-time PA N=2964		Objectively-assessed moderate-to-vigorous PA (min/day) N=6181	
	OR (95% CI)	p	exp(b) (95% CI)	p	OR (95% CI)	p	exp(b) (95% CI)	p	exp(b) (95% CI)	p
Perceived proximity to a park	**1.109 (1.059, 1.162)**	**<.001**	1.017 (0.985, 1.051)	.293	**1.081 (1.032, 1.132)**	**.001**	1.022 (0.988, 1.056)	.205	**1.028 (1.012, 1.044)**	**<.001**
No. of parks contained or	**1.027 (1.008, 1.046)**	**.005**	**1.016 (1.005, 1.028)**	**.005**	1.002 (0.984, 1.020)	.804	**1.012 (1.001, 1.023)**	**.039**	**1.007 (1.000, 1.013)**	**.048**

intersected by 1km buffer										
No. of parks contained or intersected by 0.5km buffer	1.040 (0.999, 1.082)	.055	1.019 (0.994, 1.045)	.132	1.013 (0.975, 1.053)	.495	0.999 (0.974, 1.024)	.946	**1.016** **(1.002, 1.030)**	**.024**
Area of park (any size) contained or intersected by 1km buffer (acres)	1.000 (0.999, 1.001)	.854	1.000 (0.999, 1.001)	.351	1.000 (0.999, 1.001)	.592	1.000 (0.999, 1.001)	.630	1.000 (0.999, 1.001)	.196
Area of park (any size) contained or	1.000	.739	1.000	.180	1.000	.837	1.000	.833	1.000	.344

intersected by 0.5km buffer (acres)	(0.999, 1.001)		(0.999, 1.001)		(0.999, 1.001)		(0.999, 1.001)		(0.999, 1.001)	
Distance to nearest park of any size (100m)	**0.987** **(0.978, 0.997)**	**.009**	0.998 (0.992, 1.005)	.640	0.997 (0.988, 1.006)	.516	1.000 (0.994, 1.006)	.883	1.000 (0.997, 1.003)	.999
Distance to nearest to ≤1 acre park (100m)	**0.993** **(0.988, 0.997)**	**.002**	1.000 (0.997, 1.003)	.989	1.002 (0.998, 1.006)	.373	0.999 (0.996, 1.002)	.453	**0.998** **(0.996, 1.000)**	**.017**
Distance to nearest >1 to ≤5 acres park (100m)	0.996 (0.992, 1.001)	.138	1.000 (0.997, 1.003)	.815	1.002 (0.997, 1.006)	.507	1.001 (0.998, 1.003)	.673	1.000 (0.998, 1.001)	.600

Distance to nearest >5 to ≤10 acres park (100m)	0.998 (0.994, 1.003)	.422	1.000 (0.998, 1.003)	.800	1.004 (1.000, 1.008)	.075	0.997 (0.995, 1.000)	.075	0.999 (0.998, 1.001)	.408
Distance to nearest >10 to ≤50 acres park (100m)	0.997 (0.992, 1.002)	.121	0.999 (0.996, 1.002)	.359	0.998 (0.993, 1.002)	.257	0.999 (0.996, 1.002)	.431	1.000 (0.999, 1.002)	.782
Distance to nearest >50 acres park (100m)	0.998 (0.993, 1.002)	.272	**0.997** **(0.994, 1.000)**	**.034**	0.997 (0.993, 1.001)	.116	1.001 (0.998, 1.003)	.641	1.000 (0.998, 1.002)	.996

Notes. OR = odds ratio; exp(b) = antilogarithm of regression coefficient; 95% CI = 95% confidence intervals; N = number of participants. All regression coefficients are adjusted for respondents' age, sex, marital status, educational attainment, employment status, administrative-unit socio-economic status, city, and, where appropriate, accelerometer wear time. exp(b) is to be interpreted as the proportional increase in physical activity associated with a 1 unit increase in the predictor.