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The Association Between Park Facilities and Duration of Physical Activity During Active Park Visits

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Abstract Public parks provide places for urban residents to obtain physical activity (PA), which is associated with numerous health benefits. Adding facilities to existing parks could be a cost-effective approach to increase the duration of PA that occurs during park visits. Using objectively measured PA and comprehensively measured park visit data among an urban community-dwelling sample of adults, we tested the association between the variety of park facilities that directly support PA and the duration of PA during park visits where any PA occurred. Cross-classified multilevel models were used to account for the clustering of park visits ($n = 1553$) within individuals ($n = 372$) and parks ($n = 233$). Each additional different PA facility at a park was independently associated with a 6.8% longer duration of PA bouts that included light-intensity activity, and an 8.7% longer duration of moderate to vigorous PA time. Findings from this study are consistent with the hypothesis that more PA facilities increase the amount of PA that visitors obtain while already active at a park.

Keywords Recreation · GIS · GPS · Accelerometer · Built environment

Introduction

Physical activity (PA) is associated with reduced risk of cardiovascular disease, obesity, diabetes, osteoporosis,

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and some cancers [1]. Yet more than 90% of adults in the USA do not meet the recommended 30 min of at least moderate-intensity PA on most days of the week [2]. Public parks are places often designed to support PA, [3] and investing in parks has the potential to increase population levels of PA, especially among those who cannot afford the cost of fee-based recreation or exercise opportunities (e.g., health club membership) [4]. Extensive research has focused on the relationship between physical access to parks (i.e., proximity of parks to residence) and PA, with the implicit policy question of how building more parks will increase PA [5]. Yet, it is the facilities within parks—basketball courts, playgrounds, fields, etc.—that directly support PA [6]. Perhaps a more cost-effective approach to increase park-based PA would be to add facilities to existing parks rather than build new parks [7].

The presence of certain facilities and amenities in neighborhood parks has been associated with neighborhood park-based PA [8–11]. But the facilities measured in neighborhood parks may not necessarily match the specific parks visited and used for PA. To our knowledge, only three studies have examined the relationship between facilities in specific parks and the occurrence of PA within them. In a study of 1305 residents of Odense, Denmark [12], each additional different feature in the nearest public park was associated with a 3% increase in the odds of reported use of that park for PA at least once a week. The association, however, was confounded by park size—larger parks contained more facilities and were more frequently used for PA. In an Ontario, Canada, study, Kaczynski et al. [13] examined individual-level data at the park level by testing the association between the number of park PA features and whether a park was used for PA by any of 380 adult neighborhood residents as recorded in weeklong activity diaries. The odds of any participant using a park for PA doubled for each additional PA facility, an association which was independent of park size. Stewart et al. (in review) used GPS, travel diary, and accelerometer data to identify park visits and corresponding PA bouts among Seattle area adults. Using a case-crossover study design, they found that among the 225 adults who were both active and sedentary on separate park visit occasions, each additional different park facility designed for PA was associated with a 7% increase in the probability that an individual was active during a park visit. These prior studies suggest that adding features to a park could result in more frequent use of it for at least some amount of PA. It may be that a greater variety of park PA facilities increases the likelihood that an individual visitor can find a suitable activity at a park, resulting in a visit where at least some PA occurs. A greater variety of PA facilities could also contribute to greater PA by lengthening the duration of activities, either because an individual engages in multiple activities and/or an individual finds a more suitable activity that he or she is willing to take part in for a longer period of time. To our knowledge, however, no study has directly investigated the association between the variety of park PA facilities and the duration of PA during park visits.

The present study is designed to expand the understanding of how park facilities contribute to PA by testing the association between park facilities and the duration of park-based PA. We use detailed data on park visitation among adult residents of the Seattle metropolitan area to test for an association between the variety of park facilities that support PA in the park visited and the duration of PA that occurred during a visit where any PA occurred. Park visits were measured using both objective (GPS) and subjective (travel diary) instruments, while concurrent park-related PA was measured objectively using accelerometers. These instruments overcome the limitations of reliance on only self-report PA [14] and park use [15] often present in prior research. The results will provide policy makers, active living researchers, and park managers with a better understanding of how investments in existing parks can affect the health of visitors.

Methods

Study Design and Sample

This study presents a repeated cross-sectional analysis of data from the Travel Assessment and Community (TRAC) project. The TRAC project was a longitudinal study of travel and activity in relation to light rail implementation in King County, Washington. The sample frame included King County residences in areas proximal (< 1 mile) or distal (> 1 mile) from planned light rail stations, but with otherwise similar built environments [16]. Eligible randomly selected households were contacted by telephone and a randomly selected adult was recruited if they were aged 18 or older, able to complete a travel diary and survey in English, and able to walk unassisted for ≥ 10 min. The study was approved by the Seattle Children's Hospital IRB. A total of 699 enrolled participants completed baseline data collection, 584 and 532 of whom also completed first and second follow-up data collection, respectively. Baseline data collection occurred from July 2008 to July 2009, follow-up data collection occurred 2 and 4 years later. At each time, participants completed a survey and provided data on their activities for a 1-week period. Follow-up data collection occurred at the same time of year for each participant. Data from all data collection periods were used for analysis.

Data Collection and Measures

Activity

A detailed description of the activity data collection and processing is available elsewhere [17]. Briefly, participants were instructed to wear an accelerometer (GT1M; ActiGraph LLC, Fort Walton Beach, FL, at baseline and GT3X, ActiGraph LLC, Fort Walton Beach, FL, at first and second follow-up), carry a GPS device (DG-100, GlobalSat, Taipei, Taiwan, at baseline and first follow-up and BT-1000XT GPS data logger, Qstarz, Taipei, Taiwan, at second follow-up), and complete a place-based paper travel diary for a 1-week period. Data from the three instruments for each participant were integrated by time-matching GPS and travel diary locations to each 30-s accelerometer epoch [18]. Observation days were considered valid if they had ≥ 1 place recorded in the travel diary, ≥ 3 min of GPS data, and an accelerometer wear time of ≥ 8 h. Accelerometer periods of ≥ 20 min with continuous zeroes were considered non-wear times [19].

Parks and Park Facility Exposure Measures

Park location data were collected in spring 2008 from King County and the 39 municipalities located within it and aggregated into a GIS dataset [15]. We defined parks as publicly owned, freely accessible, outdoor spaces intended for leisure or recreation and distinct from street right-of-ways. Based on this definition, we excluded aquariums, boulevards, golf courses, pools, community centers, boat launches, wilderness areas, cemeteries, and similar places unless they were located entirely within a park that did fit our definition. The combined dataset contained 1438 discrete parks.

Park facility and amenity data were then added to each park record using park management inventories. Official facility data were available for 1080 (75%) parks. Facility data for an additional 23 parks visited by participants but with official facility data not available from the initial round of public agency data collection were developed using supplemental material from public agencies or online resources such as Google maps [20]. The remaining 335 parks without facility data were not visited by participants, making it unnecessary to collect facility data. Data were recorded as the presence of 103 different facilities/amenities. Facilities/amenities were classified as PA facilities (e.g., tennis courts, fields), built amenities (e.g., barbeques, bathrooms, parking lots), and natural amenities (e.g., shorelines, greenbelts [Online Appendix A]). This classification is similar to those used by in-person park audit instruments such as the Community Park Audit Tool (CPAT) [21], the Environmental Assessment for Public Recreation Spaces (EAPRS) instrument [22], and the Public Open Space Tool (POST) [8]. For analysis, park-level facilities/amenities were measured as the count of different PA facilities, the count of different built amenities, and, due to the relatively small number, the binary presence of any natural amenities.

Parks were also characterized using GIS measures of size (acres) and mean slope. Sloping terrain within parks may contribute to views, terrain for PA (e.g., stair climbing), and/or space limitations for building facilities/amenities. Slope data came from the U.S. Geological Survey National Elevation Dataset (USGS NED). Elevation data were represented in raster datasets with a cell size of 1/3 arc second (approximately 10 m), from which mean slope in the park was calculated.

Park Visits

Park visits were defined as at least 3 consecutive minutes spent within a park and were measured using two sources: travel diaries and GPS/GIS data (16). For each place visited, participants were instructed to record in the travel diary the place name and time of arrival and departure. Travel diary places were reviewed for names matching those of public parks. Matched names were considered park visits if the duration between the arrival and departure time was ≥ 3 min. Park visits were also sensed from the GPS/GIS data using a method similar to that pioneered by Evenson et al. [23]. Sensed visits consisted of ≥ 3 min of consecutive GPS points in the same GIS park polygon, with a speed < 30 km/h and a distance of > 50 m from the participant's home and work, while allowing for gaps of ≤ 45 min. If a sensed visit temporally overlapped with a visit recorded in the travel diary, the presumably more precise park visitation duration from the GPS data was used.

Park Visit PA Outcome Measures

The primary outcome in this analysis was park visit PA time, defined as the total time spent in PA bouts within the duration of a park visit. PA bouts were defined as time intervals with vertical axis accelerometer counts > 500 per 30-s epoch for at least 5 min, allowing for counts to drop below that threshold for up to 2 min during any 7-min interval [17]. This bout definition used lower-than-usual accelerometer activity count thresholds and longer-than-usual interruption thresholds to capture light PA obtained during walking in an urban environment, which can be slow and intermittent. Walking was the most commonly reported form of park-based PA [24]. If PA bout durations extended before/after the beginning/end of a park visit, only the portion of the PA bout that occurred within the duration of the park visit was counted.

Moderate to vigorous physical activity (MVPA) time was explored as a secondary outcome. We hypothesized that a stronger association would exist between park PA facilities and MVPA time since most park facilities are designed for activities more intense than light-intensity walking. MVPA time was defined as 30-s epochs with accelerometer counts of ≥ 976 per 30-s epoch and temporally within the duration of a park visit, regardless of whether they occurred during bouts [25].

Both PA outcomes were measured in minutes and log transformed for analysis.

Other Park Visit Covariates

The presence of any park-related PA bout time that extended beyond (before or after) the duration of the park visit was measured as a potential covariate. It was intended to capture active travel, such as walking or jogging, to or from the park. We hypothesized that PA during park visits that occurred incidental to walks or jogs would have fewer facilities and shorter PA time within the park visit duration.

Characteristics of the park visit were considered potential confounders because they could be related to which park a participant chose to visit, as well as which activities a participant chose to participate in. They included the duration of the visit, quarter of year, day of week (weekend or weekday), time the visit started (before 11 am, 11 am–3 pm, and after 3 pm), mean daily temperature (°f), the presence of any precipitation during the day, whether the visit was reported in the travel diary, whether the visit was sensed from GPS data, and the network distance from the participant's home to the closest point along the park boundary (closest points were identified using Euclidean distances from home to the park boundary). Climatic measures were taken from those reported at Seattle-Tacoma International Airport by the National Oceanic and Atmospheric Administration [26].

Park Neighborhood Built Environment Covariates

Built environment (BE) features that support physical activity were measured in the neighborhood immediately surrounding each park as covariates. Park neighborhoods were delineated as 400-m Euclidean buffers from park perimeters, restricted to the contiguous land area. This buffer size was chosen to capture the 2–3 street-block area immediately surrounding each park, which could conceivably draw activity out of the park or to the park and hence confound the effect of park facilities on PA in parks. BE covariates fell under four domains commonly associated with active living and for which secondary GIS data were available: development density, destinations, transportation systems, and economic environment [27]. Density variables included net residential density and employment floor-area ratio (FAR), which is a proxy for a pedestrian-oriented site design [28]. Destination variables included count of restaurants as an indicator of utilitarian destinations and count and acreage of other parks as an indicator of nearby recreational opportunities. Transportation system variables included the count of ≥ 3-way intersections, the length of sidewalks, and the mean slope of terrain in buffer area. Due to large variations in park neighborhood buffer sizes, destination and transportation variables were standardized by buffer acreage, resulting in density measures (e.g., restaurants per park neighborhood buffer acre). Economic environment was measured as the average King County percentile of the assessed value of residential units (land + improvement).

Sociodemographic Covariates

Participants' age, gender, race and ethnicity, and highest level of education were collected only on the baseline survey; values were carried through to the first and second follow-ups (with age updated according to elapsed time). Annual household income and presence of children under age 18 in the household were collected at each observation period. Body mass index (BMI) was calculated from reported weight at each observation period and height at baseline. BMI was categorized as underweight or normal (< 25), overweight (25–29.9), and obese (≥ 30 kg/m^2). Single family vs. other residence types (apartment, condo, townhouse, other) was collected at all waves and was included as a proxy for presence of outdoor green space at home as an alternative to the outdoor green space that parks provide.

Analysis

Analysis was conducted at the park visit level. During the three observation periods, 2451 park visits occurred on valid observation days among 461 unique individuals and 317 unique parks. We focused on the 1553 park visits with any PA bout time. The 1553 park visits with any PA bout time were clustered within 372 individuals and within 233 parks. For these 1553 park visits, we first present mean park visit PA bout time by strata of each covariate (continuous covariates were dichotomized at the median to create two strata).

We then used cross-classified multilevel models (CCMMs) [29] to estimate the association between the count of different PA facilities at parks and the log-transformed duration of PA time. Model coefficients can be interpreted as the estimated multiplicative change in park-related PA time per additional type of PA facility at a park. CCMMs account for the clustering of park visits within combinations of individuals and parks through a random effects component at the individual, park, and individual-park combination level [30]. The CCMMs fit the data significantly better than both standard single-level regression models and standard hierarchical regression models with no cross-classification.

We developed CCMMs for each PA outcome by first fitting a null model with no predictors to estimate the variance partition coefficients (VPCs). VPCs are the proportion of the response variance that lies at each level of the model hierarchy [30]. In this case, the VPCs can be interpreted as the relative magnitude of the variance in PA attributable to the park visit, the individual visitor, the unique park, and individual-park combination. Next, we fit a model with only the count of different park PA facilities to estimate the crude association between the variety of park PA facilities and PA, as well as to identify how the variance in park-related PA is explained by the variety of park PA facilities. We then selected model covariates among those hypothesized to confound the association using the change-in-estimate (CIE) criterion with a 10% cutoff and fit a final model that included all covariates that individually changed the exposure-outcome estimate by 10% or more [31, 32].

Results

Park visits with any concurrent PA bout time lasted an average of 41.4 min (SD = 55.6), with an average PA bout time of 19.3 min (SD = 23.1). In this sample data, average PA bout times were longest in the winter and shortest in the summer but similar for visits above and below the median daily average temperature (55 °F) and on days with and without precipitation (Table 1). PA bout times tended to be longer during weekend visits and visits before 3 pm. Average PA bout time was longer for visits recorded in the travel diary and not sensed with GPS data. Average PA bout time was longer for visits to parks further from home and not accessed via active transportation (i.e., visits with no park-related PA bout time immediately before or after the visit). Mean PA bout time during park visits did not vary substantially by individual-level sociodemographic characteristics of park visitors (Table 2). PA time was lower in parks in less-urbanized neighborhoods, as measured by residential density, employment FAR, restaurant density, intersection density, and sidewalk density (Table 3). PA time tended to be longer in parks in wealthier neighborhoods. Larger parks and parks with more facilities or amenities tended to have longer durations of PA bout time.

Based on crude CCMM model results, PA bout time during park visits was an average of 10.0% greater for each additional different PA facility in the park (95% CI, 5.6%, 14.5%; $p < 0.001$) (Table 4). Confounding covariates, defined as variables that individually changed the PA facility-PA duration association by at least 10%, were identified in the park visit, park, and park neighborhood domains only. At the park visit level, active travel to/from the park was a confounder. Park characteristics included slope and variety of built amenities.

Table 1 Mean physical activity (PA) bout time during park visits by categories of visit-level covariates

		Park visits (n = 1553)	
Park visit-level variable	Category	n (%)	Mean (SD) PA bout time
Quarter	1st (January–March)	409 (26)	22.2 (24.8)
	2nd (April–June)	575 (37)	19.4 (24.2)
	3rd (July–September)	435 (28)	16.6 (19.1)
	4th (October–December)	134 (09)	19.1 (24.0)
Weekend	No	999 (64)	17.6 (19.6)
	Yes	554 (36)	22.5 (28.1)
Start time	Before 11 am	496 (32)	20.3 (24.1)
	11 am–3 pm	495 (32)	21.5 (26.4)
	After 3 pm	562 (36)	16.6 (18.4)
Temperature (°f)	< Median (55)	778 (50)	19.7 (22.1)
	≥ Median (55)	775 (50)	19.0 (24.0)
Precipitation	No	788 (51)	18.8 (22.6)
	Yes	765 (49)	19.9 (23.7)
Travel diary reported	No	965 (62)	14.1 (17.6)
	Yes	588 (38)	27.9 (28.0)
GPS sensed	No	131 (08)	24.8 (24.8)
	Yes	1422 (92)	18.8 (22.9)
Distance from park to home (network Km)	< Median (1.9)	778 (50)	14.0 (16.2)
	≥ Median (1.9)	775 (50)	24.6 (27.4)
Active travel to/from park (any park-related PA bout time before/after park visit)	No	390 (25)	33.1 (28.0)
	Yes	1163 (75)	14.7 (19.1)

Park neighborhood characteristics included net residential density, employment FAR, restaurant density, and slope. After adjusting for these confounders, each additional different PA facility was associated with a 6.8% longer PA bout duration (95% CI, 2.7%, 10.9%; $p = 0.001$).

Among the 1502 park visits with any MVPA time, the mean duration of park visit MVPA time was 15.6 min (SD = 19.3). Each additional different PA facility was associated with an unadjusted 10.9% greater duration (95% CI, 6.6%, 15.3%; $p < 0.001$) (Table 5). Confounding covariates were the same as for the PA bout time outcome. After adjusting for these confounders, each additional different PA facility was associated with 8.7% more MVPA time (95% CI, 4.6%, 12.8%; $p < 0.001$).

The variance partition coefficients (VPCs) for the models of PA bout and MVPA time during the park visit were similar (Tables 4 and 5). Null models indicated that most of the variance in these outcomes was at the park level (41 and 37% for PA bout and MVPA time, respectively), and a very little variance was at the individual level (5 and 3% for PA bout and MVPA time, respectively). Adding the variety of PA facilities to the model reduced the variance at the park level and the total variance; fully adjusted models further reduced the total variance, primarily through reduced variance at the park level.

Discussion

Detailed and objective measures of park facilities, park visitation, and PA that occurred during visitation allowed us to investigate the association between park facilities and the duration of PA that occurred during active park visits. Each additional different PA facility was associated with a 6.8 and 8.7% greater duration of PA bout and MVPA time, respectively, during the already active park visit. These results complement the small body of research using individual-level data that has demonstrated an association between park facilities

Table 2 Mean physical activity (PA) bout time during park visits by categories of individual-level covariates. Frequency of observations by covariate category provided for unique individuals as well as park visits

		Individuals (n = 372)	Park visits (n = 1553)	
Individual-level variable	Category	n (%)	n (%)	Mean (SD) PA bout time
Age	≤ 45	138 (38)	565 (38)	18.4 (22.6)
	45–64	173 (48)	714 (48)	20.7 (25.2)
	≥ 65	51 (14)	223 (15)	18.0 (17.7)
Gender	Female	236 (64)	1056 (68)	18.6 (21.5)
	Male	135 (36)	496 (32)	20.9 (26.2)
Race/ethnicity	Other	69 (19)	283 (18)	19.2 (20.2)
	Non-Hispanic White	300 (81)	1263 (82)	19.3 (23.7)
Education	No college degree	83 (23)	260 (17)	19.7 (25.5)
	4-year degree	133 (37)	565 (38)	20.2 (24.6)
	Graduate degree	146 (40)	676 (45)	18.7 (21.0)
Household income	< $30 k	57 (16)	179 (12)	20.5 (29.1)
	$30–$60 k	91 (26)	392 (27)	18.7 (19.7)
	$60–$90 k	71 (20)	303 (21)	21.1 (24.1)
	> $90 k	131 (37)	595 (41)	18.8 (22.6)
Children < 18 years old in household	No	249 (71)	1036 (70)	19.1 (23.6)
	Yes	104 (29)	442 (30)	20.1 (21.5)
Body mass index (k/m^2)	≤ 25	197 (57)	918 (63)	19.5 (23.5)
	25–30	97 (28)	357 (25)	19.5 (23.6)
	≥ 30	51 (15)	172 (12)	20.7 (23.4)
Single family home	No	165 (47)	601 (41)	19.9 (25.9)
	Yes	188 (53)	866 (59)	19.2 (21.5)

and the occurrence of any park-based PA [12, 13, Stewart et al., in review]. A greater variety of PA facilities within a park is associated with increases in both the occurrence and duration of park-based PA.

In the current study, each additional type of PA facility at a park was associated with an additional 1.3 and 1.4 min of PA and MVPA time, respectively, for the average active visit. While this is a small absolute amount, it has the potential to add up to substantial population health improvements when applied to all active visits that occur at a park. Adding multiple different types of PA facilities to a single park could deliver even greater increases, as exploratory analysis found the relationship between park PA facilities and PA time to be roughly linear across the entire range of different park PA facilities (0–13), but with substantial increases occurring with four or more facilities (Online Appendix B). Our results indicate that park designers should not be shy to propose to include a variety of PA facilities in parks, so long as such additional facilities do not increase safety concerns (e.g., inadequate spacing between active areas) or interfere with other important park functions, such as ecological processes, providing view sheds, or places for contemplation.

We observed only a slightly larger effect size for MVPA time compared to PA bout time that included only lighter PA, such as low-intensity walking. This suggests that park PA facilities not only contribute to relatively high-intense activities (e.g., tennis or soccer) but also contribute to lighter-intensity activities such as walking that may be more feasible for mostly sedentary or older adults.

We found that active travel to/from the park was associated with shorter durations of park-based PA for active park visits. This was as in line with our conceptualization of active travel as an indicator of a walk or run through a park, in which case the park PA facilities could be largely incidental to the duration of PA in the park. It is almost certain, however, that some in our sample used active travel to access parks for the express purpose of activities within the park—including the purpose of walking or running

Table 3 Mean physical activity (PA) bout time during park visits by categories of park-level covariates. Frequency of observations by covariate category provided for unique parks as well as park visits

		Parks (n = 233)	Park visits (n = 1553)	
Park-level variable	Category	n (%)	n (%)	Mean (SD) PA bout time
PA facility variety (count)	< Median (4)	129 (55)	466 (30)	14.9 (25.0)
	≥ Median (4)	104 (45)	1087 (70)	21.2 (22.0)
Built amenity variety (count)	< Median (2)	140 (60)	714 (46)	13.5 (18.0)
	≥ Median (2)	93 (40)	839 (54)	24.3 (25.7)
Natural amenities (any)	No	148 (64)	882 (57)	14.6 (17.7)
	Yes	85 (36)	671 (43)	25.6 (27.5)
Park size (acres)	< Median (12.0)	117 (50)	444 (29)	11.6 (16.6)
	≥ Median (12.0)	116 (50)	1109 (71)	22.4 (24.6)
Mean slope in park (percentage)	< Median (3.3)	117 (50)	670 (43)	18.9 (21.7)
	≥ Median (3.3)	116 (50)	883 (57)	19.6 (24.1)
Net residential density (units/residential acre)	< Median (9.7)	122 (52)	709 (46)	21.0 (25.7)
	≥ Median (9.7)	111 (48)	844 (54)	17.9 (20.5)
Employment FAR (employment building acre/land acre)	< Median (0.28)	119 (51)	730 (47)	23.4 (26.7)
	≥ Median (0.28)	114 (49)	823 (53)	15.7 (18.6)
Restaurant density (count/buffer acre)	< Median (0.22)	117 (50)	704 (45)	21.5 (25.2)
	≥ Median (0.22)	116 (50)	849 (55)	17.5 (21.1)
Park count (count of other parks within buffer)	< Median (3)	130 (56)	604 (39)	19.2 (20.2)
	≥ Median (3)	103 (44)	949 (61)	19.4 (24.8)
Park area density (park acre/buffer acre)	< Median (0.12)	124 (53)	669 (43)	18.8 (20.9)
	≥ Median (0.12)	109 (47)	884 (57)	19.7 (24.6)
Intersection density (count/buffer acre)	< Median (0.243)	129 (55)	544 (35)	24.9 (28.1)
	≥ Median (0.243)	104 (45)	1009 (65)	16.3 (19.3)
Sidewalk density (m/buffer acre)	< Median (0.33)	131 (56)	445 (29)	22.9 (28.0)
	≥ Median (0.33)	102 (44)	1108 (71)	17.9 (20.6)
Mean slope in neighborhood (percentage)	< Median (0.482)	123 (53)	700 (45)	19.8 (22.8)
	≥ Median (0.482)	110 (47)	853 (55)	18.9 (23.4)
Wealth (mean percentile of assessed residential unit values)	< Median (47)	127 (55)	511 (33)	15.1 (18.1)
	≥ Median (47)	104 (45)	1039 (67)	21.4 (25.0)

in the park. In this case, the observed negative relationship between active travel and park PA duration could be due to substitution—individuals may spend less time in PA in a park when they also spend time in PA getting to and from the park. Park managers, urban planners, and transportation professionals should consider how park characteristics could be used to support PA that occurs within the park, as well as park-based PA that is integrated into the built environment beyond the park boundaries.

Measures of park neighborhood development (net residential density, employment FAR) and destinations (restaurants) confounded the association between park facilities and PA duration outcomes. Greater PA durations tended to occur during active visits to parks in less-urbanized areas where the parks themselves may also be less developed and contain fewer PA facilities. Parks in less-urbanized areas may provide a more comfortable setting for activities (e.g., little traffic noise and views of nature). Park managers should consider the setting in which PA facilities are located to provide a more pleasurable sensory experience, especially in parks in more urbanized areas.

Table 4 Cross-classified multilevel model (CCMM) results for the outcome of physical activity (PA) bout time (log transformed) during park visits ($n = 1553$)

	Null		Crude		Adjusted	
Fixed effects parameters	Coefficient (95% CI)	*p* value	Coefficient (95% CI)	*p* value	Coefficient (95% CI)	*p* value
Intercept	2.190 (2.054, 2.326)	< 0.001	1.790 (1.570, 2.011)	< 0.001	2.144 (1.805, 2.483)	< 0.001
PA facility variety			0.100 (0.056, 0.145)	< 0.001	0.068 (0.027, 0.109)	0.001
Mean slope in park					0.033 (0.006, 0.06)	0.015
Built amenity variety					0.034 (−0.003, 0.07)	0.070
Net residential density					−0.003 (−0.007, 0.001)	0.158
Employment FAR					−0.006 (−0.209, 0.197)	0.956
Restaurant density					0.002 (−0.834, 0.838)	0.997
Mean slope in neighborhood					0.011 (−0.034, 0.057)	0.629
Active travel to/from park					−0.634 (−0.757, −0.511)	< 0.001
Random effects parameters	Variance (95% CI)	VPC	Variance (95% CI)	VPC	Variance (95% CI)	VPC
Individual-park combination	0.346 (0.260, 0.461)	23%	0.346 (0.259, 0.462)	24%	0.315 (0.235, 0.424)	27%
Park	0.617 (0.447, 0.853)	41%	0.511 (0.356, 0.733)	36%	0.281 (0.177, 0.446)	24%
Individual	0.070 (0.028, 0.176)	5%	0.075 (0.031, 0.180)	5%	0.073 (0.033, 0.164)	6%
Park visit	0.489 (0.440, 0.544)	32%	0.490 (0.440, 0.546)	34%	0.479 (0.43, 0.533)	42%

CI, confidence interval, *VPC*, variance partition coefficient

Prior research using direct observation observed an association between park neighborhood socioeconomic status (SES) and park PA levels [33, 34]. In our study, neighborhood wealth did not confound the association between park facility variety and duration of PA during park visits. Park neighborhood SES is likely more impactful on whether an individual visits a park at all rather than how long an individual is active during a visit.

Table 5 Cross-classified multilevel model (CCMM) results for the outcome of moderate to vigorous physical activity (MVPA) time (log transformed) during park visits ($n = 1502$)

	Null		Crude		Adjusted	
Fixed effects parameters	Coefficient (95% CI)	*p* value	Coefficient (95% CI)	*p* value	Coefficient (95% CI)	*p* value
Intercept	1.872 (1.736, 2.008)	< 0.001	1.432 (1.214, 1.651)	< 0.001	1.701 (1.354, 2.047)	< 0.001
PA facility variety			0.109 (0.066, 0.153)	< 0.001	0.087 (0.046, 0.128)	< 0.001
Mean slope in park					0.023 (− 0.005, 0.050)	0.103
Built amenity variety					0.013 (− 0.023, 0.050)	0.481
Net residential density					− 0.005 (− 0.009, 0.000)	0.043
Employment FAR					0.044 (− 0.162, 0.250)	0.673
Restaurant density					− 0.104 (− 0.938, 0.730)	0.807
Mean slope in neighborhood					0.030 (− 0.017, 0.076)	0.212
Active travel to/from park					− 0.540 (− 0.669, − 0.410)	< 0.001
Random effects parameters	Variance (95% CI)	VPC	Variance (95% CI)	VPC	Variance (95% CI)	VPC
Individual-park combination	0.437 (0.336, 0.568)	28%	0.437 (0.335, 0.569)	30%	0.393 (0.299, 0.516)	32%
Park	0.572 (0.407, 0.805)	37%	0.438 (0.292, 0.657)	30%	0.245 (0.149, 0.403)	20%
Individual	0.055 (0.015, 0.203)	3%	0.065 (0.021, 0.203)	4%	0.07 (0.027, 0.182)	6%
Park visit	0.501 (0.449, 0.559)	32%	0.502 (0.450, 0.561)	35%	0.503 (0.45, 0.561)	42%

CI, confidence interval, *VPC*, variance partition coefficient

The results of this study do not provide explicit guidance on which specific PA facilities should be added to parks to potentially make the greatest impact on park-based PA. CCMM results showed that much of the variance in PA duration occurred at the individual-park visit combination level. This implies that the amount of time an individual is active during a park visit depends largely on individual preferences for activities and whether facilities that support those activities are present at a park. Community input is likely the best way to identify which PA facilities will get the most use among those who visit or could visit or live near a specific park. Regular feedback may be necessary to ensure park PA facilities keep pace with changing community demographics and/or secular trends in recreation.

Limitations

We employed CCMMs to examine park visit data cross-classified within parks and individuals to provide a valid estimate of the association between PA facilities at parks and the duration of PA that occurs during active visits to them. This approach's drawback is that inference is limited to individuals who visit parks and are active during the visit. Further research is necessary to identify how to increase park-based PA among individuals who visit parks but are entirely sedentary, and among individuals who do not visit parks at all. Based on studies employing direct observation of parks, installing or upgrading park PA facilities often [7, 35, 36], but not always [37], leads to increases in observed levels of park use and park-based PA. But these studies cannot identify the extent to which changes are due to new park users, or existing park users visiting more often and/or staying longer. Natural experiments examining longitudinal changes to individuals' park-based PA behaviors in response to changes in park PA facilities could overcome this limitation and provide insight into how changes to PA facilities might affect those who do not often use parks for PA. This would also provide greater evidence of causation than provided by the present study, which used a cross-sectional study design and the park visit as the unit of analysis. In this approach, we assume that an individual visits a park, then is active for a duration based partially on the park's characteristics. However, it is plausible that park characteristics and activities are interdependent, based jointly on individual's interests and the characteristics of accessible parks [6]. If characteristics were to change at one park, an individual may simply choose to visit another park or be active elsewhere. Experimental or quasi-experimental study designs would be necessary to draw inference on how changes to the park environment results in broader changes in PA behavior.

This study was also limited by not being able to examine actual use of different PA facilities in parks. Direct observation of park use may be necessary to identify specific facilities that best support PA. Studies employing this methodology have found that compared to sedentary park visitors, active park visitors were more likely to be in park areas with PA facilities such as courts, paths, and playgrounds [38, 39].

The results may also be biased due to differential reporting of PA facilities across jurisdictions where parks were visited. However, the vast majority (81%, 1262 of 1553 park visits) occurred in parks with facility data provided by a single jurisdiction (Seattle). When analyses were restricted to these parks, stronger adjusted associations were observed for both PA bout duration (coefficient = 10.4%; 95% CI = 4.5%, 16.3%; p = 0.001) and MVPA duration (coefficient = 12.2%; 95% CI = 6.4%, 18.1%; $p < 0.001$). Non-differential misclassification of facilities across jurisdictions likely resulted in an attenuation of the true association. Additionally, misclassification of PA facilities may have occurred if PA facilities were installed or closed after park data were collected. A detailed assessment of park facility conditions and changes across the study period was beyond the scope of the current research. Similar studies in the future would benefit not only from consistent and timely park facility data for all parks visited but also from detailed data on the conditions of facilities and other social environment factors that may affect park visitation, such as safety and incivilities [6].

Finally, a more spatially distributed sample would also be necessary to understand if the results were generalizable beyond the highly urbanized sample used in the present study.

Conclusion

This study was the first to our knowledge to test the association between PA facilities at parks and the duration of PA that occurs during active visits. Each additional different PA facility was associated with a 6.8% longer time in PA bouts that included light activity such as slow walking. A slightly stronger association was observed for MVPA during the park visit. Adding PA facilities could increase the amount of PA that visitors obtain while active at a park, across a range of PA intensities.

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References

1. US Department of Health and Human Services. 2008 Physical activity guidelines for Americans. US Department of Health and Human Services, Washington, DC. 2008. http://www.health.gov/paguidelines/guidelines/default.aspx. Accessed 25 Feb 2014.
2. Troiano RP, Berrigan D, Dodd KW, Masse LC, Tilert T, McDowell M. Physical activity in the United States measured by accelerometer. *Med Sci Sports Exerc*. 2008;40(1):181–8.
3. Sallis JF, Floyd MF, Rodriguez DA, Saelens BE. Role of built environments in physical activity, obesity, and cardiovascular disease. *Circulation*. 2012;125(5):729–37.
4. US National Physical Activity Plan Coordinating Committee. National Physical Activity Plan. 2010. http://www.physicalactivityplan.org/NationalPhysicalActivityPlan.pdf. Accessed 23 Sep 2013.
5. Bancroft C, Joshi S, Rundle A, Hutson M, Chong C, Weiss CC, et al. Association of proximity and density of parks and objectively measured physical activity in the United States: a systematic review. *Soc Sci Med*. 2015;138:22–30.
6. Bedimo-Rung AL, Mowen AJ, Cohen DA. The significance of parks to physical activity and public health: a conceptual model. *Am J Prev Med*. 2005;28(2 Suppl 2):159–68.
7. Cohen DA, Marsh T, Williamson S, Golinelli D, McKenzie TL. Impact and cost-effectiveness of family fitness zones: a natural experiment in urban public parks. *Health Place*. 2012;18(1):39–45.
8. Giles-Corti B, Broomhall MH, Knuiman M, Collins C, Douglas K, Ng K, et al. Increasing walking: how important is distance to, attractiveness, and size of public open space? *Am J Prev Med*. 2005;28(2 Suppl 2):169–76.
9. Kaczynski AT, Besenyi GM, Stanis SA, et al. Are park proximity and park features related to park use and park-based physical activity among adults? Variations by multiple socio-demographic characteristics. *Int J Behav Nutr Phys Act*. 2014;11(1):146.
10. Kaczynski AT, Havitz ME. Examining the relationship between proximal park features and residents' physical activity in neighborhood parks. *J Park Recreat Admi*. 2009;27(3):42–58.
11. Sugiyama T, Francis J, Middleton NJ, Owen N, Giles-Corti B. Associations between recreational walking and attractiveness, size, and proximity of neighborhood open spaces. *Am J Public Health*. 2010;100(9):1752–7.
12. Schipperijn J, Bentsen P, Troelsen J, Toftager M, Stigsdotter UK. Associations between physical activity and characteristics of urban green space. *Urban For Urban Green*. 2013;12(1):109–16.
13. Kaczynski AT, Potwarka LR, Saelens BE. Association of park size, distance, and features with physical activity in neighborhood parks. *Am J Public Health*. 2008;98(8):1451–6.
14. Sallis JF, Saelens BE. Assessment of physical activity by self-report: status, limitations, and future directions. *Res Q Exerc Sport*. 2000;71(2 Suppl):S1–14.
15. Stewart OT, Moudon AV, Fesinmeyer MD, Zhou C, Saelens BE. The association between park visitation and physical activity measured with accelerometer, GPS, and travel diary. *Health Place*. 2016;38:82–8.
16. Moudon AV, Saelens BE, Rutherford S, Hallenbeck M. A report on participant sampling and recruitment for travel and physical activity. Transportation Northwest Regional Center X (TransNow), University of Washington. 2009. http://ntl.bts.gov/lib/31000/31700/31738/VernezMoudon_EffectofLight_Rail.pdf. Accessed May 05 2014.
17. Kang B, Moudon AV, Hurvitz PM, Reichley L, Saelens BE. Walking objectively measured: classifying accelerometer data with GPS and travel diaries. *Med Sci Sports Exerc*. 2013;45(7):1419–28.
18. Hurvitz PM, Moudon AV, Kang B, Saelens BE, Duncan GE. Emerging technologies for assessing physical activity behaviors in space and time. *Front Public Health*. 2014;2:2.
19. Masse LC, Fuemmeler BF, Anderson CB, et al. Accelerometer data reduction: a comparison of four reduction algorithms on select outcome variables. *Med Sci Sports Exerc*. 2005;37(11 Suppl):S544–54.
20. Taylor BT, Fernando P, Bauman AE, Williamson A, Craig JC, Redman S. Measuring the quality of public open space using Google earth. *Am J Prev Med*. 2011;40(2):105–12.
21. Kaczynski AT, Stanis SA, Besenyi GM. Development and testing of a community stakeholder park audit tool. *Am J Prev Med*. 2012;42(3):242–9.
22. Saelens BE, Frank LD, Auffrey C, Whitaker RC, Burdette HL, Colabianchi N. Measuring physical environments of parks and playgrounds: EAPRS instrument development and inter-rater reliability. *J Phys Act Health*. 2006;3(Supplement 1):S190–207.
23. Evenson KR, Wen F, Hillier A, Cohen DA. Assessing the contribution of parks to physical activity using global positioning system and accelerometry. *Med Sci Sports Exerc*. 2013;45(10):1981–7.
24. Godbey G, Mowen A. *The benefits of physical activity provided by park and recreation services: the scientific evidence*. Ashburn, VA: National Recreation and Park Association; 2010.
25. Gorman E, Hanson HM, Yang PH, Khan KM, Liu-Ambrose T, Ashe MC. Accelerometry analysis of physical activity and sedentary behavior in older adults: a systematic review and data analysis. *Eur Rev Aging Phys Act*. 2014;11:35–49.
26. National Oceanic and Atmospheric Administration. Global Historical Climatology Network-Daily. http://www.ncdc.noaa.gov/oa/climate/ghcn-daily/. Accessed August 01 2014.
27. Stewart OT, Carlos HA, Lee C, Berke EM, Hurvitz PM, Li L, et al. Secondary GIS built environment data for health

research: guidance for data development. *J Transp Health*. 2016;3(4):529–39.
28. Saelens BE, Sallis JF, Frank LD, et al. Neighborhood environment and psychosocial correlates of adults' physical activity. *Med Sci Sports Exerc*. 2012;44(4):637–46.
29. Beretvas SN, Meyers JL, Rodriguez RA. The cross-classified multilevel measurement model: an explanation and demonstration. *J Appl Meas*. 2005;6(3):322–41.
30. Leckie G. Cross-classified multilevel models. *LEMMA VLE Module*. 2013;12:1–60. http://www.bristol.ac.uk/cmm/learning/course.html. Accessed 20 Sep 2014.
31. Lee PH. Should we adjust for a confounder if empirical and theoretical criteria yield contradictory results? A simulation study. *Sci Rep*. 2014;4:6085.
32. Weng HY, Hsueh YH, Messam LL, Hertz-Picciotto I. Methods of covariate selection: directed acyclic graphs and the change-in-estimate procedure. *Am J Epidemiol*. 2009;169(10):1182–90.
33. Baran PK, Smith WR, Moore RC, Floyd MF, Bocarro JN, Cosco NG, et al. Park use among youth and adults: examination of individual, social, and urban form factors. *Environ Behav*. 2014;46(6):768–800.
34. Van Dyck D, Sallis JF, Cardon G, et al. Associations of neighborhood characteristics with active park use: an observational study in two cities in the USA and Belgium. *Int J Health Geogr*. 2013;12:26.
35. Tester J, Baker R. Making the playfields even: evaluating the impact of an environmental intervention on park use and physical activity. *Prev Med*. 2009;48(4):316–20.
36. Veitch J, Ball K, Crawford D, Abbott GR, Salmon J. Park improvements and park activity: a natural experiment. *Am J Prev Med*. 2012;42(6):616–9.
37. Cohen DA, Golinelli D, Williamson S, Sehgal A, Marsh T, McKenzie TL. Effects of park improvements on park use and physical activity: policy and programming implications. *Am J Prev Med*. 2009;37(6):475–80.
38. Shores KA, West ST. The relationship between built park environments and physical activity in four park locations. *J Public Health Manag Pract*. 2008;14(3):e9–16.
39. Floyd MF, Bocarro JN, Smith WR, Baran PK, Moore RC, Cosco NG, et al. Park-based physical activity among children and adolescents. *Am J Prev Med*. 2011;41(3):258–65.