



Objectively measured active travel and uses of activity-friendly neighborhood resources: Does change in use relate to change in physical activity and BMI?

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ABSTRACT

Few studies examine how objectively measured use of local physical activity resources contributes to objectively-measured healthy physical activity and weight changes over time. We utilized objective measures to test whether changes in active travel and uses of three physical activity (PA) resources—parks, recreation centers, and transit—related to changes in PA and BMI. Adults ($n = 536$) in Salt Lake City, UT, wore accelerometer and GPS units in 2012 and 2013, before and after neighborhood rail completion. Regression outcomes included accelerometer counts per minute (cpm), MVPA (moderate-to-vigorous activity minutes/10 h accelerometer wear) and measured BMI; key predictors were changes in active travel and PA resource uses (former and new uses). Significant results (all $p < 0.05$) showed that increased active travel related to increased total PA (59.86 cpm and 8.50 MVPA); decreased active travel related to decreased MVPA (-3.01 MVPA). Poorer outcomes were seen after discontinuing use of parks (-36.29 cpm, -5.73 MVPA, and $+0.44$ BMI points), recreation centers (-6.18 MVPA), and transit (-48.14 cpm, -5.43 MVPA, and $+0.66$ BMI). Healthier outcomes were seen after commencing use of parks (29.83 cpm, 5.25 MVPA), recreation centers (44.63 cpm) and transit (38.44 cpm, 4.17 MVPA, and -0.56 BMI). Transit and park/recreational center uses were unrelated, although park users were more likely to be recreation center users. Active travel and use of three neighborhood PA resources relate to healthy activity and could be fostered by policy and design.

1. Introduction

Increasingly, policymakers recognize that activity-friendly community designs can create opportunities for active travel, other forms of physical activity (PA), and healthy weight (Heath et al., 2006). Research on PA associated with using community facilities such as parks, recreation centers, and transit is accumulating (Moody et al., 2004; Owen et al., 2004), although often limited to cross-sectional self-reported uses of one type of PA facility (Evenson et al., 2013). We use GPS/GIS and accelerometry to pinpoint whether changes in active travel and uses of three particular modifiable neighborhood PA resources—public transit (bus, light rail, or commuter rail), parks, and recreation centers—relate to PA and weight changes.

Changes in active travel are seldom studied as a source of PA, although one UK study found changes in active travel corresponded to changes in total PA, but not to changes in recreational PA (Sahlqvist et al., 2013). The authors argued these results supported more development of active travel policies, although it is unknown whether such

findings would replicate in the U.S., where active travel is less frequent (Bassett et al., 2008), or for objectively measured PA, which is often much lower than self-reported PA (Troiano et al., 2008).

Parks near home are a common venue for activity, especially among males (Cohen et al., 2007) and walking groups (Schoffman et al., 2015). However, residents living close to parks have been found to walk less than residents living far from parks (King et al., 2012), perhaps due to a dearth of other walkable destinations near parks (King et al., 2015). Furthermore, few park user studies measure objective MVPA attained in parks; one study that showed park visits entailed 2.3 MVPA minutes (Evenson et al., 2013) and another found they involved approximately 4.9 MVPA minutes (Stewart et al., 2016). No studies were found that examined objective PA associated with recreation center use or change in use, although proximity to recreation centers has been related to more self-reported PA (Hirsch et al., 2013; Humpel et al., 2002).

Transit use typically requires active travel to/from the stations, although few studies measure changes in transit use over time. In the current study a new light rail transit line was extended as part of a Salt

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Lake City “complete street” intervention, in which a street is renovated to be more supportive of active travel by pedestrians, cyclists, and transit riders (Smart Growth America, 2016). This renovation included five new rail stops, improved sidewalks, bike lanes, and landscaping. Generally, transit riders show more total objectively measured PA (Chaix et al., 2014; Saelens et al., 2014; Wener and Evans, 2007), although in one case only for those who were less active initially (Hong et al., 2016). In our past research, residents who started using the complete street transit post-construction were found to have increased their cpm and MVPA (Brown et al., 2015), especially for days riding transit (Miller et al., 2015), and reduced their BMI (Brown et al., 2015), with similar findings for PA bouts among Seattle transit riders (Saelens et al., 2014). We anticipate similar results for transit ridership in the current study, where transit ridership involves any transit ride, not limiting riders to those within the complete street corridor. One concern is whether using time-consuming transit might reduce one's leisure PA (Lachapelle et al., 2016). Positive (Gordon-Larsen et al., 2009; Sugiyama et al., 2010), negative (Collins and Agarwal, 2015) and null (Kwasniewska et al., 2010; Sahlqvist et al., 2012) relationships between active travel and recreational PA have been found, using cross-sectional data and self-reported PA. Thus, we examine whether transit ridership, park, and recreation center uses are interrelated.

For a cohort of adults in 2012–2013, we test whether objectively measured a) active travel changes relate to changes in accelerometer cpm, MVPA, and BMI; b) uses of neighborhood parks, recreation centers, and transit are interrelated; and c) changes in neighborhood facility use relate to changes in cpm, MVPA, and BMI.

2. Methods

2.1. Participants

Adults were recruited in an area up to 2 km north and south of the complete street renovation area (approximately a 4 × 4.2 km area, between 200 West and 1950 West on North Temple). They wore accelerometers (Actigraph GT3+, Actigraph, Pensacola, FL) and GPS data loggers (GlobalSat DG-100, New Taipei City, Taiwan) for approximately 1 week in 2012 and 2013, pre- and post-renovation (see details in Brown et al., 2014). Eligible adults from randomly sampled blocks included those who could walk a few blocks, spoke English or Spanish, were not pregnant, anticipated remaining in the neighborhood for a year, gave informed consent as approved by the authors' institution, and provided at least 3 days of ≥ 10 h/day accelerometer wear along with GPS data. Accelerometer non-wear time was defined as 60 min of 0 cpm, allowing for two interruptions of up to 100 cpm (Troiano et al., 2008); one re-wear was allowed if participants did not meet eligibility.

Due to these screening requirements and a recruitment area that did not match census boundaries, the representativeness of the sample cannot be definitive. As might be expected from screening out participants who did not expect to live there for one year, there were fewer renters in the sample (48%) than in the census neighborhood (59%). The sample was more representative of area gender (51% female sample, 48% area), Hispanic ethnicity (24% and 26%), and age (42 & 44 years old) (Brown et al., 2016).

This study includes 536 adults with valid data who remained in the study in 2012 and 2013. There were 939 participants at time 1 (March–December 2012). By time 2 (May–November 2013), 403 participants were lost to follow-up: 283 participants moved, 77 did not have valid GPS data, 34 refused, and 9 became ineligible. Incomplete GPS data are common, in part because the devices needed to be charged daily and do not reliably record inside buildings (Krenn et al., 2011) (see additional description of this sample in Brown et al., 2014).

2.2. Procedures

Researchers met with participants, typically in their homes, to secure informed consent, administer surveys and provide equipment wearing instructions. Researchers returned after a week to administer final surveys, measure weight and height, and download data from the devices to a secure website, designed by GeoStats (now Westat) to merge the time-stamped accelerometer minutes to GPS/GIS data and assign travel modes.

2.3. Variables

2.3.1. Dependent variables: cpm, MVPA, and BMI

Outcome variables were difference scores calculated as 2013 minus 2012 values of average cpm per approximately one week of accelerometer wear (Strath et al., 2012), MVPA minutes/10 h accelerometer wear, and measured BMI. Accelerometer cpm can provide useful comparison data to studies using similar accelerometer units but different PA intensity cut-points (Strath et al., 2012) as well as providing an overall PA measure. To interpret cpm, it is useful to know that obese adults have about 45 fewer cpm than overweight adults and overweight individuals have about 12 fewer cpm than healthy weight adults (Tudor-Locke et al., 2010). A 2020 cpm threshold for MVPA was adopted (Troiano et al., 2008). Heights and weights were measured following NHANES protocols (Centers for Disease Control and Prevention, 2005), using calibrated scales and portable stadiometers, with BMI defined as kg/m.²

2.3.2. Active travel

Following Sahlqvist et al. (2013) we examine how change in active travel durations relates to total PA change. GeoStats combined accelerometry and GPS/GIS data to identify minutes of active travel, based on speed, location, and acceleration data (see details of identification of trip ends, trip modes, and identification of travel mode transitions in Miller et al., 2015). Active travel is any non-automotive travel. It is typically walking, which averaged 2.83 mph across the full sample (SD = 1.22), but could include biking and jogging. Active travel designations require ≥ 1 min of active travel and can include MVPA. Active travel change scores (years 2013 minus 2012) were divided into thirds to represent increased (top third, cutpoint ≥ 4.39 min active travel change per 10 h GPS wear), decreased (bottom third, ≤ -1.44 min change), and unchanged (middle third reference group) active transportation.

2.3.3. Park use

The 25 parks (omitting small “tot” lots of ≤ 1 block, see map in Appendix) within 4 km of neighborhood boundaries were included, a distance comparable to average travel to parks (Stewart et al., 2016). Accelerometer minutes of activity were merged to the first GPS point within each minute. Park users were defined as those with ≥ 1 MVPA (2020 cpm) minute of activity that had ≥ 1 GPS points within GIS-defined park boundaries, excluding any sidewalks bounding the park. Participants were effect-coded into four groups based accelerometer/GPS evidence of use during the one-week measurement periods each year. For park users this included: never users (did not use park in 2012 or 2013; coded -1 for never, 0 otherwise), continuing users (in 2012 and 2013), former users (in 2012 but not 2013), and new users (in 2013, but not 2012; the latter three groups are coded 1 for use, 0 otherwise). We recognize that these group labels derive from approximately one week of data for each of the two time periods and should not be considered enduring categories; a “never user” might have used a park, but not during our measurement periods.

2.3.4. Recreation center use

The two government-owned multipurpose recreation centers within 4 km of neighborhood boundaries were included. The centers offer

swimming pools, indoor tracks, exercise classes and equipment, youth and adult sports, as well as childcare. Again, active use of the facilities required ≥ 1 min of MVPA matched to at least one GPS reading within approximately 5 m buffer around the recreation center. Because GPS signals can be lost inside buildings, recreation center users were manually verified by following their GPS traces to and away from the building. In cases where individuals took off their accelerometer during a recreation center visit, daily logs were checked to verify if they reported swimming or weight lifting that day in order to impute that they achieved ≥ 1 min MVPA. User groups again included the four groups: never, continuing, former, and new recreation center users.

2.3.5. Transit trip

Any bus, light rail, or commuter rail trips, inside or outside the neighborhood, were included as transit travel; the city's light rail system was extended to the neighborhood in 2013. Transit use across two years resulted in four groups: never, continuing, former, and new riders.

2.3.6. Control variables

Control variables included gender, age, education (college graduate or not), and time 1 device wear time (accelerometer wear time merged with all time in GPS trips) and baseline outcome variables (i.e., time 1 cpm, MVPA/10 h wear, and BMI). Other control variables included change scores (time 2–1) for employment (full or part-time = 1, 0 otherwise), participation interval (days between time 1 and 2 participation), device wear time, temperature, self-reported health (“In general, how has your health been lately?” with response 1 to 4, “poor” to 4 = “excellent”), and automobile travel time, which sometimes relates to less PA (Chaix et al., 2014). Device wear times were equivalent for all non-users compared with their park, recreation center, and transit user counterparts (all *t*-tests, *n.s.*).

2.4. Data analyses

Descriptive statistics were computed and chi-square analyses tested the relationships among transit, park, and recreation center use. In regression analyses, change scores for outcome variables of the two PA measures—cpm and MVPA—as well as BMI were related to changes in active travel and then, separately, to changing use of particular neighborhood PA resources. No problematic levels of multicollinearity were detected (i.e., all tolerances > 0.1). Missing data were minimal and analyses run without missing cases, reducing the *n* from 536 to 525.

3. Results

Descriptive statistics in Table 1 show about half of participants were female, with an average age of almost 42 and 37% had a college degree.

3.1. Change in active travel and change in PA and BMI

As the significant effects in Table 2 demonstrate, residents who increased their active travel (i.e., those in the top third of change scores) increased their total PA by 59.86 cpm ($p < 0.001$), and their MVPA by 8.50 min ($p < 0.001$). Those who decreased active travel decreased total MVPA minutes by -3.01 min ($p < 0.05$). Change in active travel was not related to change in BMI (both $p > 0.05$).

3.2. Relationships between uses of neighborhood resources

The proportions in Table 3 reveal that a) few neighborhood residents—between 9% and 27%—used each resource during the weeks of measurements; b) transit use was unrelated to park and recreation center use (χ^2 (d.f. = 9) = 8.36, $p = 0.50$ and 5.21, $p = 0.82$, respectively), although park and recreation use were related (χ^2 (d.f. = 9)

Table 1
Descriptive statistics of sample.

Characteristic	Proportion or mean	SD
Female	0.51	0.50
Age, years	41.72	14.77
College graduate	0.37	0.48
Device wear time (in hours, time 1)	86.03	19.70
Employment change	0.03	0.39
Health change	- 0.02	0.69
Temperature change	7.52	19.37
Participation day change	346.29	64.64
Auto duration change (in hours)	- 0.47	25.90
Device wear time change (in hours)	0.36	24.38
Active travel minutes per 10 h		
2012	11.61	13.83
2013	14.18	19.00
Change	2.57	18.62
PA counts per minute (cpm)		
2012	323.18	147.34
2013	332.15	150.81
Change	8.97	122.05
MVPA per 10 h		
2012, minutes	20.39	17.88
2013, minutes	21.00	18.46
Change	0.61	15.90
Body mass index (BMI)		
2012	28.99	7.00
2013	29.24	7.00
Change	0.21	1.82

Note. MVPA = moderate to vigorous physical activity. Data are from Salt Lake City, UT, USA 2012 and 2013.

Table 2
Active travel change tertiles: change score regressions for accelerometer PA counts (cpm), MVPA, and BMI (2013 – 2012).

Outcome variables	b	SE	95% CI
PA counts per minute (cpm)			
Increasing active travel	59.86	11.2	(37.85, 81.86)***
Decreasing active travel	- 19.60	11.26	(- 41.73, 2.53)
Moderate-to-vigorous physical activity (MVPA)			
Increasing active travel	8.50	1.44	(5.67, 11.34)***
Decreasing active travel	- 3.01	1.46	(- 6.25, - 0.40)*
Body mass index (BMI)			
Increasing active travel	- 0.37	0.19	(- 0.75, 0.01)
Decreasing active travel	0.08	0.20	(- 0.31, 0.46)

Note. Boldface indicates statistical significance (* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$). Control variables are gender, age, education, time 1 accelerometer wear time, time 1 outcome values, changes in employment, temperature, self-reported health, participation interval, automotive time, and accelerometer wear time. Salt Lake City, Utah, USA.

Table 3
Patterns of facility use across time: proportions of residents in each category.

Proportions:	Never	Continuing	Former	New
Park user	0.74	0.06	0.12	0.09
Recreation center user	0.91	0.02	0.03	0.05
Transit user	0.73	0.10	0.08	0.10
Proportions among users				
Park user	-	0.22	0.43	0.35
Recreation center user	-	0.18	0.34	0.48
Transit user	-	0.35	0.29	0.36

Data collected in 2012 & 2013 in Salt Lake City, Utah, USA.

Table 4
Changes in park, recreation center, and transit use: Change score regressions for accelerometer counts (cpm), MVPA, and BMI (2013–2012).

		b	SE	95% CI
Outcome variable park users				
PA counts per minute	Continuing	21.60	15.76	(− 9.36, 52.56)
	Former	− 36.29	12.16	(− 60.19, − 12.40)**
	New	29.83	13.17	(3.95, 55.71)*
MVPA	Continuing	3.23	2.05	(− 0.80, 7.25)
	Former	− 5.73	1.58	(− 8.83–2.63)***
	New	5.25	1.71	(1.88, 8.61)**
Body mass index	Continuing	− 0.15	0.27	(− 0.67, 0.38)
	Former	0.44	0.21	(0.04, 0.84)*
	New	− 0.29	0.22	(− 0.72, 0.15)
Recreation center users				
PA counts per minute	Continuing	− 4.74	28.01	(− 59.96, 50.46)
	Former	− 38.2	22.75	(− 82.90, 6.50)
	New	44.63	20.2	(4.95, 84.32)*
MVPA	Continuing	2.08	3.66	(− 5.11, 9.26)
	Former	− 6.18	2.97	(− 12.01, − 0.36)*
	New	3.36	2.63	(− 1.80, 8.51)
Body mass index	Continuing	− 0.21	0.47	(− 1.14, 0.72)
	Former	− 0.08	0.38	(− 0.83, 0.67)
	New	0.16	0.34	(− 0.51, 0.83)
Transit riders				
PA counts per minute	Continuing	8.95	13.09	(− 16.76, 34.66)
	Former	− 48.14	13.55	(− 74.77, − 21.52)***
	New	38.44	12.67	(13.54, 63.33)**
MVPA	Continuing	1.89	1.72	(− 1.49, 5.27)
	Former	− 5.43	1.76	(− 8.90, − 1.97)**
	New	4.17	1.65	(0.93, 7.41)*
Body mass index	Continuing	− 0.01	0.22	(− 0.44, 0.42)
	Former	0.66	0.23	(0.21, 1.11)**
	New	− 0.56	0.21	(− 0.97, − 0.14)**

Note. Boldface indicates statistical significance (* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$). Control variables are gender, age, education, time 1 accelerometer wear time, time 1 outcome values, changes in employment, temperature, self-reported health, participation interval, automotive time, and accelerometer wear time. Salt Lake City, Utah, USA.

= 31.20, $p < 0.001$); and c) there was substantial change across years in use of each resource.

To illustrate the chi-square analyses, among transit riders 24% used parks; among non-transit riders 27% used parks. Among transit riders, 6% used a recreation center; among non-transit riders, 10% used a recreation center. In contrast, among neighborhood area park users ($n = 142$), 15% also used a recreation center in one or both years; among park non-users ($n = 394$), only 7% used a recreation center in one or both years. Thus, transit ridership is relatively unrelated to park or recreation center use; in contrast, park users are more likely to be recreation center users than are non-park users.

The proportions of users varies substantially—from 0.18 to 0.48—across the continuing, former, and new categories, as shown in the bottom half of Table 3. Typically, the groups that represent former and new users have > 1/3rd of users in them, again demonstrating substantial change across the two measured weeks.

3.3. Change in neighborhood resource use and change in PA and BMI

As shown in Table 4, significant effects showed that former neighborhood area park users decreased their cpm by -36.29 ($p < 0.01$), their MVPA by -5.73 min ($p < 0.001$), and their BMI by 0.44 points ($p < 0.05$). New park users increased their cpm by 29.83 ($p < 0.05$) and their MVPA by 5.25 ($p < 0.01$).

Former recreation center users significantly decreased their MVPA by -6.18 ($p < 0.05$). In addition, new recreation center users increased their cpm by 44.63 ($p < 0.05$).

Former transit riders decreased their cpm by -48.14 ($p < 0.001$) and their MVPA by -5.43 min ($p < 0.01$); they gained 0.66 BMI

points ($p < 0.01$). New transit riders increased their cpm by 38.44 ($p < 0.01$) and their MVPA by 4.17 min ($p < 0.05$) and decreased their BMI by -0.56 points ($p < 0.01$).

4. Discussion

Few studies examine both the known sources of PA, such as active travel, and multiple modifiable neighborhood PA resources, such as parks, recreation centers, and light rail or other transit uses. Active travel, measured by GPS and accelerometry, was consistently related to PA outcomes. In addition, analyses of changes in all three specific sources of PA—transit, park, and recreation center use—were related to total PA changes, as measured by accelerometer counts per minute and MVPA minutes. The relationships varied little between accelerometer counts per minute and MVPA minutes per 10 h of accelerometer wear. These results add confidence and specificity to results of studies with self-reported active travel changes in relationship to recreational and total activity (Sahlqvist et al., 2013). According to these results, making both instrumental (transit) and recreational (park and recreation center) physical activities available to neighborhood residents will benefit those who choose to use the resources, without having one type of activity cancel out the benefits of the other.

Transit use changes were associated with PA and BMI changes, corroborating past research (Saelens et al., 2014), including research with the current dataset where transit users had been restricted to those using transit trips on the complete street (Brown et al., 2015; Miller et al., 2015). New transit riders increased cpm and MVPA and lost BMI, while former transit riders lost cpm and MVPA and gained BMI. Continuing transit riders did not change activity or BMI. This research extends past research by examining both general activity—active travel—as well as uses of modifiable local resources and comparing transit to recreational use. We found that recreational activity, measured objectively by use of parks and recreation centers, was not associated with transit use. That is, participants who started using transit did not compensate for the extra travel time by reducing GPS/accelerometer-defined use of local parks and the recreation center. Nor did those who stopped using transit change their patterns of recreational facility use. For health advocates, these results, if replicated elsewhere, suggest the health benefits of transit use do not erode health benefits from park or recreation center use, given that use patterns did not change with transit ridership changes. Similarly, the health benefits of transit use accrue to individuals who had not been using other neighborhood PA resources.

Given that transit riders were not especially likely to be park and recreation center users, these results speak to a lost opportunity. Transit ridership is not exposing participants to any new park or recreation resources in a way that makes their use especially likely. Given the low levels of PA in the U.S. and elsewhere, it may be advisable to think about how one healthy neighborhood activity might bridge to other healthy physical activities. Currently, there are no advertising or policy supports for connecting transit use to recreational place use, but such ideas may be worth considering. To the extent that new transit stops could be designed with PA possibilities in mind, such as providing stationary bikes or swings (Nordahl, 2012) at the stops, accommodating bicycles on transit vehicles, or assuring recreational places are served by transit, then individuals may begin to connect their active travel transit trips to recreational outlets. Although parks are often located in outlying transit deserts, connecting urban parks to transit may be useful, as might providing PA opportunities near urban sports venues, such as sports team stadiums. Similarly, those whose primary objective is to exercise may see the advantage of using public transit.

Recreational uses were more complementary in that park users were especially likely to be recreation center users. For communities trying to maximize PA opportunities, research into the co-locations of parks, recreation centers, and transit stops is warranted.

Changes in activity and BMI associated with GPS-verified uses of

neighborhood PA resources are seldom measured and tracked over time. However, past research relying on self-reports suggests substantial change over time in neighborhood PA. For example, over two thirds of the UK sample of Sahlqvist et al. (2013) reported a change in active travel by ± 15 min a week (Sahlqvist et al., 2013). Similarly, 73% of a UK sample reported changes in active commutes (Foley et al., 2015). The current study demonstrated that residents show substantial changes over a year in their use of neighborhood PA facilities, regardless of whether those facilities changed. For example, new users included 36% of transit riders, 35% of park users, and 48% of recreation center users. Additional research is needed to understand why PA resource use is so fluid and whether interventions might transform sporadic users into continuing users of these facilities.

4.1. Limitations

Although objective measurement of use of PA resources is a strength of the study, a weakness is that only one week was sampled each year; thus, “never” users may be infrequent users who did not happen to use the facility during the study weeks. These results need replication over longer measurement durations. Defining park and recreation use as requiring ≥ 1 min of MVPA also does not differentiate between short and long MVPA uses. Furthermore, some participants had no active travel, so results are unlikely to represent very sedentary individuals. The trip mode transition identification was time consuming, but future algorithms may automate this process more fully. We also did not measure diet, which might clarify whether the BMI changes were solely due to PA changes. It will be troubling for public health if longer data collection intervals in future research confirm that participants often stop using PA resources, a pattern found in other studies of self-reported PA (Sahlqvist et al., 2013). We recommend future researchers provide

survey data to explore the reasons for starting and stopping use of neighborhood PA resources.

4.2. Conclusions

These results show that increased active travel, transit use, park use, and recreational center uses all relate to increased levels of PA and transit and park use were associated with increased or decreased BMI in the expected directions. Reducing use of these resources was always related to decreased levels of PA. These results gain strength from the use of objective measures and the modeling of change over time. Community PA resources provide a healthy option for neighborhood residents, although residents taking advantage of neighborhood transit were not especially likely to use neighborhood recreational places, or vice versa. Creative design and policy resources are needed to encourage neighborhood residents to take advantage of a broader range of these resources over a longer time interval.

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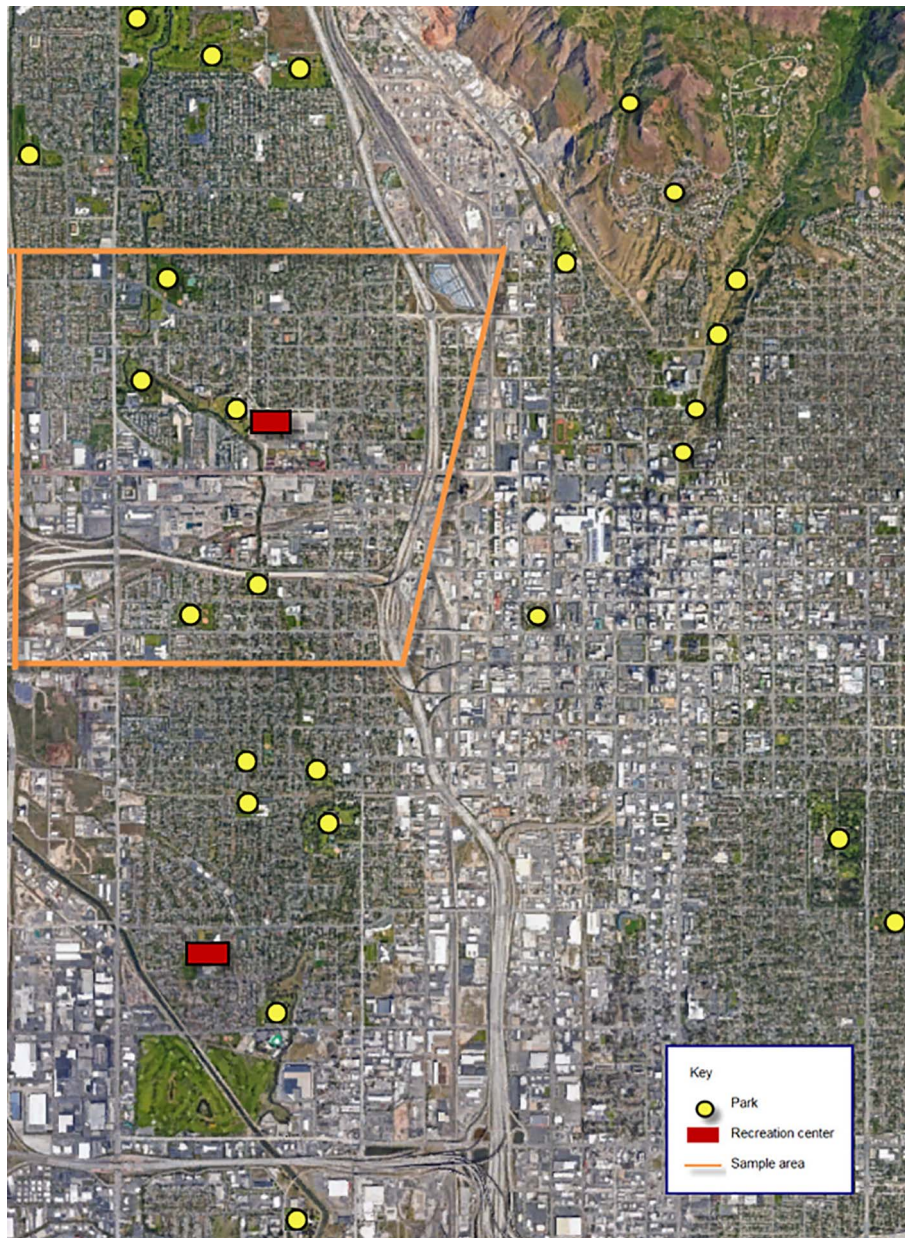
Conflict of Interest

The authors declare there is no conflict of interest.

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Appendix A



Appendix. Map of Salt Lake City neighborhood sample area and parks and recreation centers. Map data ©2017 Google.

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