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How Far from Home? The Locations of Physical Activity in an Urban U.S. Setting

Philip M. Hurvitz, PhD[a], **Dr Anne V. Moudon, es Sc**[a], **Bumjoon Kang, PhD**[b], **Megan D. Fesinmeyer, PhD, MPH**[c], and **Brian E. Saelens, PhD**[c,d]

Philip M. Hurvitz: phurvitzQuw.edu; Anne V. Moudon: moudonQuw.edu; Bumjoon Kang: bumjoonkQbuffalo.edu; Megan D. Fesinmeyer: Megan.FesinmeyerQseattlechildrens.org; Brian E. Saelens: brian.saelensQseattlechildrens.org

[a]Urban Form Lab, Box 354802, University of Washington, Seattle, Washington 98195-4802, USA

[b]Department of Urban and Regional Planning, 114 Diefendorf Hall, University at Buffalo, State University of New York, New York 14214-8032, USA

[c]Seattle Children's Research Institute, 2001 Eighth Ave Seattle, WA 98121, Seattle, Washington 98195-4802, USA

[d]Department of Pediatrics, Box 356320, University of Washington, Seattle, Washington 98195-6320, USA

Abstract

Little is known about where physical activity (PA) occurs, or whether different demographic groups accumulate PA in different locations.

1. Method—Objective data on PA and location from 611 adults over 7 days were collected in King County, WA in 2008-2009. The relative amounts of time spent in sedentary-to-low and moderate-to-vigorous PA (MVPA) were quantified at three locations: “home” (<125 m from geocoded home locations); “near” home (125 - 1,666 m, defining the home neighborhood); and “away” from home (> 1,666 m). Differences in MVPA by demographics and location were examined. The percent of daily time in MVPA was estimated using a mixed model adjusted for location, sex, age, race/ethnicity, employment, education, BMI, and income.

2. Results—Most MVPA time occurred in nonhome locations, and disproportionately “near” home; this location was associated with 16.46% greater time in MVPA, compared to at-home activity ($p<0.001$), whereas more time spent at “away” locations was associated with 3.74% greater time in MVPA ($p<0.001$). Location was found to be a predictor of MVPA independent of demographic factors.

3. Conclusion—A large proportion of MVPA time is spent at “near” locations, corresponding to the home neighborhood studied in previous PA research. “Away” locations also host time spent in MVPA and should be the focus of future research.

Correspondence to: Philip M. Hurvitz, phurvitzQuw.edu.

1. Introduction

Higher levels of physical activity (PA) are known to provide many health benefits (Warburton et al., 2006); likewise, greater time spent in sedentary activities is linked with negative health outcomes (Owen et al., 2010; Powell and Blair, 1994). Many adults fail to achieve health-benefiting levels of PA (Matthews et al., 2008; Troiano et al., 2008), so a better understanding of the fundamental characteristics of PA has potential for improving strategies to increase this health behavior. Multiple observational studies have reported PA level variation by demographics: men are more physically active than women, and age, education, income, and race/ethnicity are consistently associated with different levels of PA (Carlson et al., 2010; Gordon-Larson et al., 2000; Hawkins et al., 2009; Macera et al., 2005; McCracken et al., 2007; Troiano et al., 2008). Studies have shown that PA levels are associated with residential built environment characteristics (Cohen et al., 2006; Forsyth et al., 2008; Kaczynski and Mowen, 2011; McConville et al., 2011; McCormack et al., 2008; Rodríguez et al., 2008), yet few studies have considered non-residential locations of PA (Inagami et al., 2007; Muntaner et al., 2006), with some focusing on the work place (Conn et al., 2009; Dannenberg et al., 2005). Because daily movements typically extend beyond residential neighborhoods (Naess, 2006), research should take a comprehensive view of multiple locations in order to fully characterize the influence of environment on PA.

A substantial literature addresses time use, i.e., where and when people engage in various activities. The American Time Use Survey (ATUS, http://www.bls.gov/tus), a self-reported survey of the previous day's activities, has been used to classify the social and physical environments of time spent in sports, exercise, and recreation by named location (Dunton et al., 2008), About 1/4 of sports and exercise time occurred outside, about 1/4 at home, and <10% at work or gym/health clubs, respectively. ATUS data showed that more vigorous and moderate PA occurred outdoors, followed by gym/health club, home, and work (Dunton et al., 2009). Although the ATUS data are detailed about the named location of places and contexts where activity occurred, they do not contain information on spatial location with respect to home.

Until recently, collecting objective data simultaneously on PA levels and the locations in which that PA occurs has been difficult. Studies using GPS and accelerometry have opened new avenues to investigate PA levels as they occur across locations (Cooper et al., 2010; Hurvitz and Moudon, 2012; Jones et al., 2009; Mackett et al., 2005; Quigg et al., 2010; Rodríguez et al., 2012; Troped et al., 2010). Assessing PA across the places where one goes, these studies found great variation in PA levels across individuals and by built environment (BE) characteristics, with substantial amounts of MVPA occurring outside participants' residential neighborhood. The present study improves upon previous research for several reasons: a large sample size of both participants and objective data, no data reduction, and a measurement frame encompassing complete weekly activity spaces.

GPS and accelerometer data were used to examine geographic patterns of PA over a one-week period. The study further aimed to identify where different demographic groups engaged in PA, as well as whether the proportion of active time spent in different locations differed by demographic characteristics. Knowing where PA, and particularly moderate-to-vigorous PA, actually occurs is essential for public health officials and policy makers to better target policies and programs seeking to increase PA and to improve PA-supportive environments.

2. Methods

2.1. Data

Data came from the Travel Assessment and Community Study (TRAC), whose aim was to investigate longitudinal effects of a new light rail transit (LRT) system on walking behavior. Sampling and recruitment protocols have been reported previously (Kang et al., 2013; Moudon et al., 2009). Briefly, participants residing close to (cases) and distal from (controls) proposed light rail stops, but in similar neighborhood BEs, were recruited using address and phone data. Eligibility included being at least 20 years old, able to complete a survey and travel diary in English, and able to walk unassisted for at least 20 minutes. Consented participants (N=750) were asked to complete a sociodemographic survey, to wear both GlobalSat DG-100 GPS units and Actigraph GT1M accelerometers for one week, and to complete a concurrent place-based travel diary. Data collection spanned February, 2008 to June, 2009. Subjects gave written consent before enrollment, and all study procedures were approved by the Seattle Children's Research Institute IRB.

On the survey, participants reported sex, age, weight, height, household income (at $50k USD intervals), education level (less than college graduate vs. college graduate or greater), race/ethnicity (recategorized as “non-Hispanic White” and “other”), and employment (full-time, part-time, or retired/unemployed). Weight and height were transformed to BMI (kg/m^2): underweight and normal (≤25), overweight (25.1-29.9), and obese (≥30).

2.2. Data development

Differentiating wear and nonwear accelerometer time—Accelerometry data were first processed to flag lengthy “nonwear” periods of at least 20 min registering zero movement. Days were determined to be valid if they contained at least 8 hours of “wearing” accelerometry data and had at least one travel diary place record (Mâsse et al., 2005; Reilly et al., 2006). Within each 24-hour day, periods of nonwear were then identified as intervals of ≥ 60 min of zero counts with ≤ 2 consecutive min of 1-50 counts per 30 s epoch (CPE) (Matthews et al., 2008).

Merging activity and location data—Data from the 30 s epoch accelerometer-based activity counts and the 30 s interval GPS locations were compiled into subject-level, time-indexed “LifeLogs.” (Hurvitz et al., 2014; Kang et al., 2013) For each accelerometry record, attributes of the temporally closest GPS record (within 60 s) were joined, creating a single table containing accelerometry counts and XY coordinates. Only raw device data were used; no GPS or accelerometry data were imputed. Accelerometer records without GPS data were considered missing at random after ANOVA tests showed no significant differences between accelerometer counts with and without GPS locations.

Geocoding home location—Home addresses from the survey were geocoded to parcel centroids using King County, WA address point GIS data for reference within ArcGIS 9.3.1

(ESRI, 1999). For subjects living in large parcels (≥ 0.8 ha = 2 ac), home locations were estimated as the centroid of GPS coordinates falling within the subject's home parcel.

2.3. Measurements

PA level cut-points—PA levels were defined using established thresholds: sedentary (≤150), low (150-1951), moderate (1952-5274), and vigorous (≥5275) (Freedson et al., 1998; Kozey-Keadle et al., 2011). The standard CPE cutoff values were divided by two to account for a 30 s measurement epoch. Activity levels were dichotomized as sedentary/low PA (SLPA) and moderate/vigorous PA (MVPA).

PA location—Due to the large number of subjects and LifeLog records, data were stored and processed using PostgreSQL 9.1.9 (The PostgreSQL Global Development Group, 2008) and PostGIS 1.5.3 (The PostGIS Development Group, 2008). Geometry fields (for spatial calculations) were added to the LifeLog tables from XY coordinates. The distance between each subject's LifeLog record location and the geocoded home location point was measured using the straight-line "ST_Distance" function, and stratified per subject into three location classes: "*home*" (<125 m); "*near*" home (125-1,666 m); and "*away*" from home (>1,666 m), as shown in Figure 1. The "home" cutoff of 125 m was used to represent an approximately 1 block-face radius centered at the home location (Hurvitz, 2010). The "away" cutoff of > 1,666 m represents the distance traveled in 20 minutes at a typical walking pace of 5 km/h (Browning et al., 2006; Murtagh et al., 2002), and moderately greater than the 1 km radius often used to represent the readily accessible home neighborhood (Saelens and Handy, 2008; Yang and Diez-Roux, 2012).

2.4. Analysis

Time spent daily in each activity level and location class was calculated individually for all subjects using Equation 1: the mean daily proportion of time spent (*y*) in activity level *i* for participant *k*. The equation adjusts for subject-level variability in wearing hours and valid days. Differences in the proportion of time spent in SLPA and MVPA by location were examined by individual demographic characteristics. Kruskal-Wallis tests were used to compare among sociodemographic classes for each location. An α level of 0.007 was used to define significance due to the number of independent comparisons (0.05 / 7 $\approx$ 0.007).

$$y_{ik}=\frac{\sum_{j=1}^{d_k}\frac{t_{ij}}{t_j}}{d_k} \quad (1)$$

where t = duration

i = 1, 2, …, 6 (activity+location class)

j = 1, 2, …, d_k (subject-day)

k = 1, 2, …, n (subject)

A mixed model approach was used to evaluate the association between location and proportion of time spent in MVPA. The "xtmixed" command in Stata 12 (StataCorp, 2011) was used to implement the model, which included subject as a random effect, and location ("home", "near,"and "away"), age, employment, BMI, income, race/ethnicity, education, and sex as fixed effects. Standard errors were calculated using a maximum likelihood approach, using an observed information matrix. The model coefficients for "near" and "away" locations estimate the average percentage point difference in time spent in MVPA compared to the "home" location, after adjustment for model covariates.

To evaluate possible interactions between location and demographic factors on the proportion of time spent in MVPA by location, pairs of mixed models were developed and compared using a likelihood ratio test. For each demographic covariate, one model included a location covariate interaction term, and a second model omitted the interaction term but included location and the covariate separately in the model. The "lrtest" command in Stata was used to estimate the likelihood ratio χ^2 value and corresponding p-value. Sex, BMI, and education, being among the most consistent demographic correlates of physical activity, were evaluated in three model pairs.

3. Results

The final sample consisted of 611 participants with at least one valid day determined by accelerometry, any GPS data, and demographic data. Most subjects were female (61.2%) and between 40 and 65 years old (64.6%, Table 1). The sample was predominantly non-Hispanic White (80%), with over 50% fully employed, and highly educated (70.7% college graduates). About 1/2 were overweight or obese. The proportion of participants of lower and middle income was similar (37.8% and 40.6%, respectively), with 21.6% of subjects earning >$100,000.

3.1. Wearing and nonwearing time

From the 4,328 valid days, a total of 6,711,068 LifeLog records were collected. Of these, 4,017,966 (59.9%) were classified as accelerometer wearing and with GPS locations, yielding a mean of 8.2 h (SD 4.1 h) per day.

3.2. Time spent at different locations by activity level

Most time was spent at "home" (51%), followed by "away" (37%), and "near" locations (12%; Table 2 and Figure 2a). Time spent in different activity levels varied by location. At "home" and "away" locations, the overwhelming majority of time was spent in SLPA (96% and 88%, respectively). In contrast, only about 65% of time at "near" locations was in SLPA, with 35% spent in MVPA. However, participants spent the least amount of time at "near" locations.

Nearly 90% of time, or 7.6 h per day (SD 4 h) was spent in SLPA (Figure 2b). About 55% of SLPA time was spent at "home", and 37% at "away" locations. Conversely, nearly 80% of MVPA time occurred at "near" and "away" locations combined.

Across locations, amount of time generally decreased by PA level (Table 2). For SLPA, the proportion of time spent in different locations varied significantly, whereas for moderate and vigorous PA, there were no significant differences across locations. The count of records in different activity levels was consistent for different subsets of data availability (e.g., all wearing records, records with or without GPS locations; data not shown), indicating that there was negligible bias in using only records with GPS locations.

3.3. Demographic differences in activity by location

Time spent in MVPA varied significantly by demographics and location ($p<0.007$, Table 3). Men's “home” and “away” time had higher PA than women's. The proportion of “home” activity time decreased with age. Employment status was related to different proportion of “home” time being active. Lower proportions of active time occurred at “near” and “away” locations for less educated, other than non-Hispanic White, and higher BMI participants.

Results of the mixed model evaluating the effect of location and demographics showed significant variation in the proportion of active time spent in MVPA by location, education, and BMI (Table 4). The coefficients represent the percentage point difference in time spent in MVPA for each category compared to the reference category. Compared to activity occurring at “home” locations, activity occurring at “near” and “away” locations averaged 16.46% and 3.74% greater time in MVPA, respectively ($p<0.001$).

Compared to college graduates, less educated participants spent 2.88% less time in MVPA ($p=0.003$), and obese participants spent less time in MVPA (-4.07%, $p<0.001$).

Evaluation of effect modification by demographics revealed no evidence of interaction with sex or education. In contrast, the association between location and MVPA time differed significantly by BMI (Likelihood ratio $\chi^2 = 12.18$, $p = 0.016$). There was no significant difference in MVPA time spent at “home” locations across BMI groups ($p=0.942$), but there were significant differences for “near” and “away” locations (both $p<0.001$), with substantially less MVPA for obese participants.

4. Discussion

This study uniquely reports on where objectively measured PA occurred based on a large population sample assessed over an entire week. Results convincingly show that time spent in different physical activity levels is unevenly distributed by location, and that the greatest proportion of MVPA time occurs away from home. Additionally, there were differences in MVPA time by demographic groups within different locations; lower education attainment and higher BMI status were associated with a lower proportion of activity time spent in MVPA, while adjusting for location.

Finding that “near” and “away” locations each hosted about 40% of total time spent in MVPA has several implications for research and policies on PA. First, given the dearth of research focusing on PA at “away” locations, one must assume such activity includes work, recreation, or utilitarian activities. Clearly, future research is needed to understand how and where MVPA takes place in these “away” locations.

Second, the greater proportion of time spent in higher activity levels at “near” locations highlights the need to continue examining possible impacts of residential neighborhood BE on activity levels, as these “near” locations were within walking distance of participants' homes. While time spent at these locations accounted for about 12% of total PA time, more than 1/3 of this time was spent in MVPA, a much higher proportion than “home” or “away” MVPA (4.4% and 11.5% of total time, respectively). This suggests that producing residential neighborhood environments supporting PA might in turn promote increases in MVPA. The promise was reinforced by substantial variation among participants' MVPA time at “near” locations, which could be explained by differences in BE characteristics; for example, participants with greater “near” MVPA time may reside in more walkable neighborhoods. Furthermore, whereas some demographic factors were related to differences in physical activity within location type, the lack of effect modification by age, sex, income, and race/ethnicity indicates that BE changes might fuel PA increases across a broad demographic range.

Third, the sizable proportion of time spent in MVPA at “near” locations suggests that numerous past studies examining the relationship between activity and the residential neighborhood environment have indeed focused on places where MPVA is more likely to occur (Chaix et al., 2012; Frank et al., 2006; Hoehner et al., 2005; Lee and Moudon, 2006a,b; Moudon et al., 2006; Rutt and Coleman, 2005; Sundquist et al., 2011). Furthermore, the commonly used 10- to 20-minute walking distance from home (about 833 m to 1,666 m) used to define residential neighborhood corresponds to the “near” radius used in this study, corroborating this distance as appropriate to delineate the MVPA-supportive neighborhood.

On the other hand, the small amount of time allocated to MVPA (10.8%) was in line with past studies, underscoring the urgency of addressing this public health concern (Brownson et al., 2005; Matthews et al., 2008). Opportunities to reduce SLPA also appear to be linked to location. For example, nearly 90% of “away” time (and an even higher percentage of “home” time) was spent in SLPA, suggesting the need for PA research based on “away” activity space (e.g., work), with particular focus on environmental effects.

This study had several limitations. Little difference was found in the proportion of time spent in different PA levels by GPS coverage, suggesting that GPS coverage was missing at random. However, as only 60% of LifeLog accelerometer data had GPS coverage, it is possible that assignment of the remaining 40% of non-located data to different PA levels could change the measured time in these different PA levels.

Nevertheless, given this constraint, we focused on relative time spent in SLPA and MVPA by location, and could not draw conclusions on absolute time spent in PA. Systematic differences in missing data by demographic groupings and location could change model results in ways that cannot be determined.

Also, this sample was randomly selected from a spatial frame comprising those with similar, and highly walkable neighborhoods; findings may not be representative of the region or generalizable to other areas. However, similar analyses could be applied to data from the increasing number of studies that have collected GPS and accelerometry data.

This study investigated the relative location where PA occurred, but did not consider specific BE characteristics of these locations. Future research including both location and environment may elucidate the effect of places where PA actually occurs; BE characteristics may explain some of the variation in location-specific MVPA. Knowledge of how specific environmental features are related to location-specific activity could aid in policy and design interventions for increasing PA.

5. Conclusions

This study showed that PA levels varied significantly by location. While participants spent a small total amount of time in MVPA, MVPA occurred mainly in nonhome locations, and disproportionately at locations within walking distance of homes. Therefore, research and policies focusing on the residential neighborhood appear to properly aim at PA-supportive environments. As well, however, more research is needed on MVPA spent in "away" environments. Finally, as education and BMI status seem to influence time spent in PA, policies and interventions aiming at increasing PA may be more effective when targeted not only at specific locations, but also at specific populations.

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Highlights

- We measured objective location and physical activity for 611 persons for 1 week.
- We evaluated differences in time spent in MVPA by location and demographics.
- Less MVPA time was spent at or away from home; more was spent "near" home.
- Lower education and higher BMI were associated with lower MVPA time by location.
- Location predicted time spent in MVPA independent of demographics.

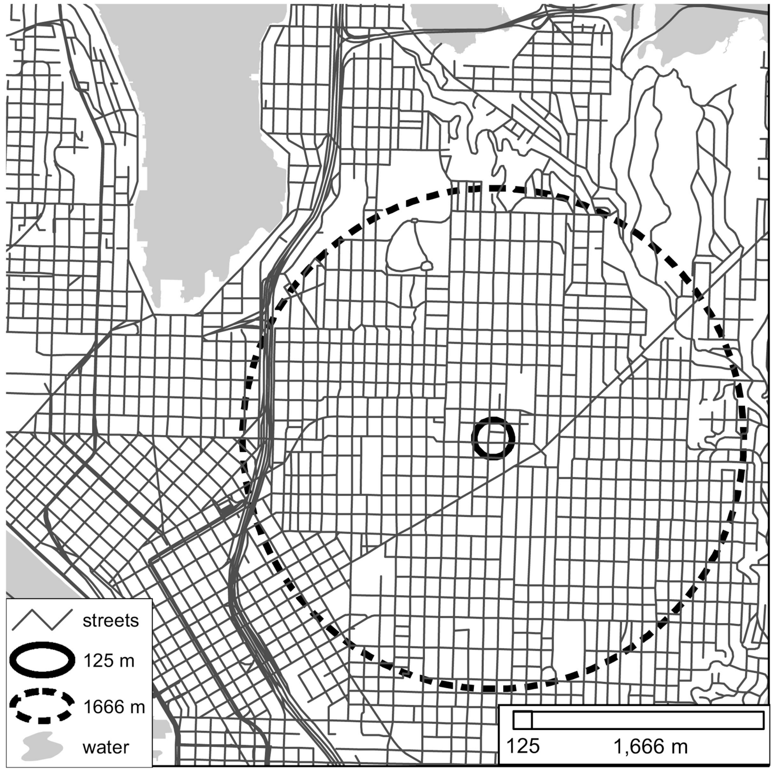

Figure 1.
Map showing the three location classes around a participant's home: home (<125 m), “near” home (125-1,666 m), and “away” from home (>1,666 m).

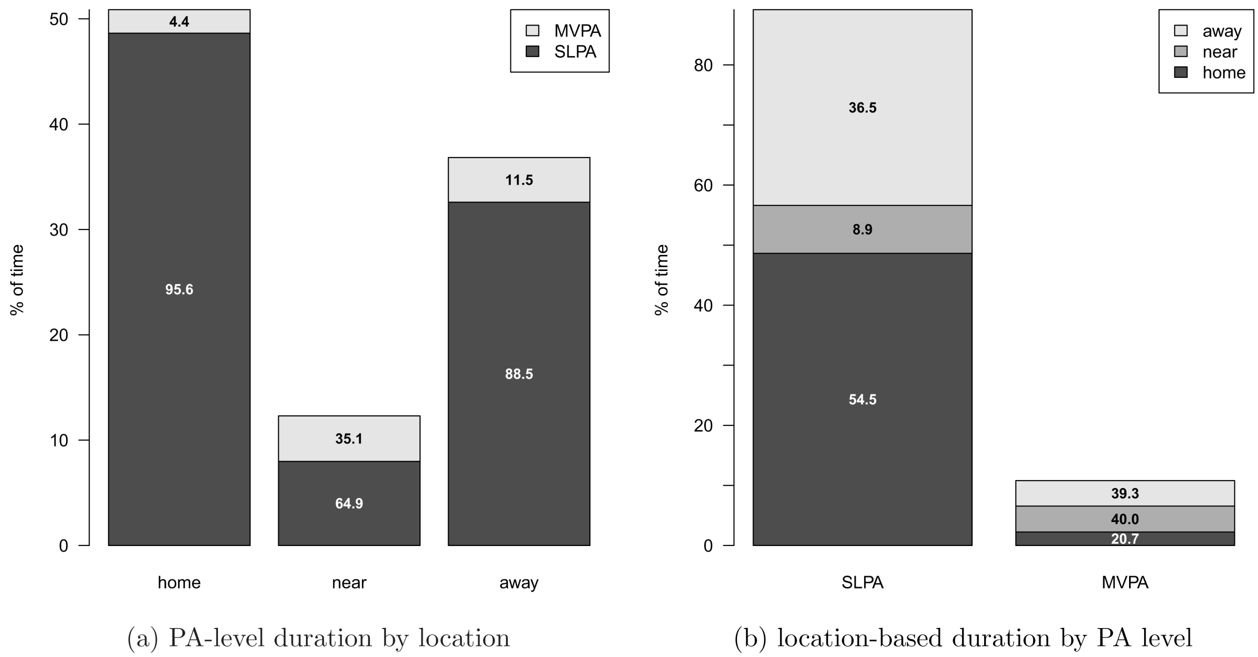

Figure 2.

Time allocation by location and PA class, 2008-2009, King County, WA; within-class percentages are printed in each cell

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Table 1
Sample characteristics, 2008-2009, King County, WA

	n	%
female	374	61.2
male	237	38.8
<40	135	22.1
40-65	395	64.6
>65	81	13.3
non-Hispanic white	489	80.0
other	122	20.0
full-time	326	53.4
part-time	148	24.3
retired/unemployed	136	22.3
less than college graduate	179	29.3
college graduate or higher	432	70.7
normal	291	47.6
overweight	190	31.1
obese	130	21.3
<50k	231	37.8
50-100k	248	40.6
>100k	132	21.6

Table 2

Physical activity duration by location and PA levels for valid records, 2008-2009, King County, WA

	home			near			away			
PA	**mean[1]**	**SD[1]**	**%**	**mean**	**SD**	**%**	**mean**	**SD**	**%**	**p-value**
sedentary	183.3	90.7	36.0	29.9	25.1	5.9	125.5	79.7	24.7	0.000
low	68.6	34.3	13.5	11.4	9.4	2.2	43.2	29.1	8.5	0.000
moderate	7.1	4.9	1.4	13.2	9.0	2.6	13.1	10.3	2.6	0.334
vigorous	2.0	0.7	0.4	6.0	2.5	1.2	5.4	2.5	1.1	0.353
all	51.3			11.9			36.9			

[1] mean and standard deviation (SD) in minutes

Table 3

Percent of all PA time spent in MVPA[1] by location and demographic characteristics, 2008-2009, King County, WA

	all locations	home		near		away	
	mean (SD)	**mean (SD)**	**p-value**	**mean (SD)**	**p-value**	**mean (SD)**	**p-value**
female	7.4 (7.9)	6.6 (11.3)	**0.004**	24.3 (19.5)	0.707	10.6 (11.7)	**0.004**
male	9.0 (8.1)	8.8 (12.6)		23.8 (17.2)		12.0 (12.3)	
<40	8.2 (7.8)	9.5 (15.0)	**<0.001**	22.8 (16.6)	0.337	10.0 (8.7)	0.425
40-65	8.3 (8.1)	7.2 (11.0)		24.8 (19.0)		11.2 (11.9)	
>65	6.3 (7.9)	5.0 (8.6)		22.4 (20.1)		13.3 (16.6)	
non-Hispanic White	8.2 (8.3)	7.3 (12.0)	0.701	25.1 (19.0)	**0.006**	11.3 (12.3)	0.936
other	7.4 (6.7)	7.8 (11.1)		19.6 (16.4)		10.7 (10.3)	
less than college graduate	6.5 (6.0)	6.4 (10.4)	0.016	20.5 (18.1)	**0.002**	9.3 (10.3)	**0.003**
college graduate or higher	8.6 (8.6)	7.9 (12.4)		25.4 (18.7)		11.9 (12.5)	
<50k	7.9 (8.3)	7.5 (12.1)	0.336	23.2 (18.8)	0.371	12.2 (14.8)	0.592
50-100k	8.0 **(7.8)**	7.1 (10.9)		24.1 (18.8)		10.4 (9.8)	
>100k	8.3 (7.9)	7.8 (13.0)		25.4 (18.0)		11.0 (10.3)	
full-time	8.2 (7.9)	7.6 (11.4)	**<0.001**	23.6 (18.6)	0.278	11.1 (11.1)	0.457
part-time	7.6 (6.6)	6.3 (10.6)		25.9 (18.6)		10.5 (11.0)	
retired/unemployed	8.1 (9.6)	8.2 (13.9)		23.1 (18.8)		12.2 (14.8)	
normal	8.7 (8.5)	7.7 (12.7)	0.942	26.2 (18.4)	**<0.001**	12.6 (12.7)	**<0.001**
overweight	8.4 (8.2)	7.3 (11.7)		23.7 (18.2)		11.3 (11.9)	
obese	6.0 (5.9)	7.0 (9.8)		19.3 (19.1)		7.4 (9.0)	

[1]Percentages refer to the ratio of MVPA to all PA time within a location and demographic class, rather than to the grand total, and therefore do not sum to 100%

Bold indicates significance at the p = 0.007 level.

Table 4

Mixed model results (marginal effect of location on MVPA), 2008-2009, King County, WA

	coef.	SE	P>|z|	95% CI
home[1]				
near	16.46	0.82	<0.001	14.85 to 18.08
away	3.74	0.64	<0.001	2.48 to 5.00
female[1]				
male	1.37	0.85	0.11	-0.30 to 3.04
40-65[1]				
<40	-0.49	1.01	0.63	-2.46 to 1.48
>65	-2.1	1.42	0.14	-4.88 to 0.68
non-Hispanic White[1] other	-0.91	0.96	0.34	-2.79 to 0.97
college graduate or higher[1] less than college graduate	-2.88	0.97	0.003	-4.78 to -0.98
50-100k[1]				
<50k	1.25	1.07	0.24	-0.84 to 3.35
>100k	-0.04	1.07	0.97	-2.12 to 2.06
full-time[1]				
part-time	-0.24	1.02	0.81	-2.25 to 1.77
retired/unemployed	1.28	1.25	0.3	-1.16 to 3.72
normal[1]				
overweight	-1.13	0.96	0.24	-3.02 to 0.75
obese	-4.07	1.09	<0.001	-6.21 to -1.93

[1] reference category