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Increased Walking's Additive and No Substitution Effect on Total Physical Activity

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Abstract

Purpose—We assessed the associations between a change in time spent walking and a change in total physical activity (PA) time within an urban living adult sample, to test for additive or substitution effects.

Methods—Participants living in the greater Seattle area were assessed in 2008–2009 and again 1–2 years later (2010–2011). At each time point, they wore accelerometers and GPS units and recorded trips and locations in a travel diary for 7 consecutive days. These data streams were combined to derive a more objective estimate of walking and total PA. Participants also completed the International Physical Activity Questionnaire to provide self-reported estimates of walking and total PA. Regression analyses assessed the associations between within-participant changes in objective and self-reported walking and total PA.

Results—Data came from 437 participants. On average, a 1-minute increase in total walking was associated with an increase in total PA of 1 minute, measured by objective data and 1.2-minute, by self-reported data. A similar additive effect was consistently found with utilitarian, transportation, or job-related walking, measured by both objective and self-reported data. For recreational walking, the effect of change was mixed between objective and self-reported results.

Conclusion—Both objective and self-reported data confirmed an additive effect of utilitarian and total walking on PA.

Keywords

Longitudinal Study; Accelerometer; GPS; Self-reported Measures; IPAQ

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Introduction

Public health advocates are increasingly focusing on promoting walking as a means to obtain more physical activity (PA). Walking is one of the most popular types of PA because it can be easily accommodated in everyday routines and does not require special equipment or expenditures (1). Given that short, moderate-level PA bouts may have substantial health benefits (2), increasing the number of even short bouts of walking over the course of daily life could be an effective and inexpensive way to increase total PA (3). Accordingly, a growing number of national and international policy interventions are designed to increase walking activity (1, 4). The success of these interventions will depend on whether more walking results in more total PA. However, more walking may in fact substitute for other forms of PA. For example, a campaign that successfully results in people changing their commute mode from driving to walking, but also leads to decreases in discretionary recreational walking or PA time, may yield no change or even decreases in total PA. Whether there are substitution or additive effects between PA types and therefore overall PA is a crucial question to properly gauge the effectiveness of future interventions to increase PA.

A small body of literature examining the contribution of structured, prescribed, or supervised exercise PA to total PA, suggests an additive effect and offered minimal evidence of a substitution effect between PA types among children or general adult populations (5, 6). However, among older adults, some substitution effects were found (6). It is not clear whether the results of such studies, which were conducted under highly controlled PA conditions (e.g., laboratory-based aerobic exercise on specific cycle ergometers) can be generalized to PA performed under free-ranging conditions (e.g., unstructured everyday walking).

In contrast, a few cross-sectional studies found a possible substitution effect of walking on total PA. Comparing participants living in high- and low-walkability neighborhoods, studies found that while total PA did not significantly differ between participants living in either of the two types of neighborhoods, those living in high-walkability neighborhoods spent more time walking than those in low-walkability neighborhoods (7, 8). This pointed to a possible neighborhood-level substitution effect, where the contribution of walking to PA was related to the neighborhood level of walkability. However, these studies had cross-sectional designs, group-level comparisons, and subjective PA measurements involving social-desirability and recall biases, suggesting the need for further research to examine the dynamic interactions between walking and other types of PA, with objective data.

The present study sought to compare longitudinal changes in walking with changes in total PA using a within-participant design. Few studies have examined longitudinal changes in walking and different types of PA (9). Two studies comparing within-participant longitudinal changes focused on walking solely for commuting and total PA. They found that more walking to and from work had an additive effect on total PA (10, 11). However, they solely or partly relied on subjective measurements of walking and PA, with potential limitations of self-report measurement errors.

Based on an urban adult sample, the present study uses both objective and subjective PA measurement frameworks to investigate whether increases in walking were associated with additive or substitution changes in total PA. The current analysis is an observational study. We analyzed within-participant PA changes over time under free-ranging conditions. Factors related to potential changes in PA levels, including life transition and PA perception, as well as home neighborhood built environment characteristics, were controlled for in analysis. Because different types of walking may have different relationships with total PA (12, 13), we also tested the relationship between different types of walking (utilitarian, recreational, transportation, job-related) and changes in total PA.

Methods

Study Design and Sample

Data came from the Travel Assessment and Community (TRAC) project, which aimed to assess whether changes in transportation infrastructure result in changes in PA. Participants were selected using a spatial sampling process designed to capture populations in relatively high-density, walkable, and transit-accessible areas. The detailed sampling and recruitment process was published elsewhere (14). In brief, we identified 773 Census block groups with approximately 390,000 residential units in the greater Seattle urban area. Within the block groups, participants were recruited by telephone and screened for eligibility, including being 20 years old, able to walk outside the home without assistance, and able to read and speak English. Participants provided informed consent to participate, and the study was approved by Seattle Children's Research Institute's Institutional Review Board. TRAC participants who were included in these analyses first provided data between July 2008 and July 2009 (Wave 1 [W1]). They were re-contacted and provided another round of data at the same time of year between July 2010 and July 2011 (Wave 2 [W2]).

Walking and PA Data Measurement Framework

The study relied on both objective and subjective PA measures, at each wave, because the two data frameworks have strengths and weaknesses that complement each other (15). Models analyzed objective and subjective PA data separately. Whether subjectively or objectively measured, PA data included total PA, total walking, and subclasses of walking (utilitarian/transportation, recreational, and job-related).

Objective PA Measurement—Objective PA data came from combined accelerometer, GPS, and travel diary data from 7 consecutive days at W1 and W2, respectively. Participants were instructed to wear an accelerometer (GT1M at W1 and GT3X at W2, Actigraph LLC, Pensacola, FL) on the hip, to wear or carry a GPS unit (DG-100 GPS data logger, GlobalSat WorldCom Co., Taipei, Taiwan at W1 and BT1000XT, Qstarz International Co., Taipei, Taiwan at W2), and to record travel in a diary (modified from the National Household Travel Survey place-based formats). Both the accelerometer and GPS were set to record data every 30 s and worn during waking times except for aquatic activities (e.g., swimming, showering).

PA bouts were first identified as time spent in moderate or vigorous PA, which was defined as intervals with sustained accelerometer values ≥ 500 vertical-axis counts per 30 s epoch (cpe) for a minimum of 5 minutes. The cut point of 500 cpe was chosen to capture walking with speed of ≥ 3 km/h (16). Because there is no strong consensus of cut points (17), we evaluated the sensitivity of analysis results for other cut points of 600, 700, 800, 900, and 1000 cpe. Second, walking bouts were identified from PA bouts using a rule-based walk classification algorithm applied to time-integrated GPS and travel diary data (18). Third, recreational walking bouts were defined as having no destination; if a walking bout's first and last GPS points were at the same location (distance < 40.2 m—the average locational error distance of the GPS device) or the bout was concurrently recorded as 'tour' in the travel diary (trip without a stated destination), it was considered recreational walking. Conversely, any walking bouts not deemed recreational were assumed to be utilitarian walking. Detailed processes for walking type classification are provided elsewhere (manuscript submitted for review). Total PA, total walking, utilitarian walking, and recreational walking were calculated as daily average minutes in PA bouts in total or these categories of bouts.

Subjective PA Measurement—Subjective PA measurements were obtained at each wave from IPAQ-LF items included in a psychosocial survey (19). The IPAQ-LF asks about frequency (how many days a certain type PA was conducted for at least 10 minutes at a time) and average duration (how much time usually spent on one of those days conducting that PA type) during the 7 days preceding the survey, for 11 types of moderate or vigorous PA under 4 separate domains. Daily average minutes in each PA type were calculated by multiplying their respective frequencies and durations. Total PA was the sum of daily minutes in all PA types. Transportation walking, job-related walking, and recreational walking were identified from their corresponding three types of PA in the IPAQ-LF. We considered utilitarian walking as the sum of transportation and job-related walking.

Data Collection and Final Sample—First, we conducted initial data screening. The criteria included (i) participants having returned survey data, (ii) having ≥ 5 days with any GPS data, (iii) having ≥ 6 days with any travel diary records, and finally (iv) having ≥ 6 d with accelerometry data ≥ 8 h after removing nonwearing intervals defined as consecutive zeros in the accelerometer count for at least 20 min (20). Participants who did not meet the initial screening were asked to re-participate in the assessment. Second, data collection was followed by analyses of data validity. Participants having no objective PA bouts during the assessment periods were excluded from the analysis, as were participants who moved to a different home addresses between waves. Invalid person days, defined as days having PA bouts with no GPS or no travel diary data, were also excluded from the analyses. Finally, participants with extreme PA values (> 4 hr/day in either wave) were also excluded.

Demographics and PA Perceptions

Analyses included control variables, which may affect changes in walking or PA amounts and types, were selected from prior studies (21, 22). Life transition factors might affect changes in walking and total PA (22); and changes in PA perception and social support for PA could also influence different types of PA (23).

Analyses included time-invariant demographic characteristics such as age, sex, race/ethnicity, and education (some college or below vs. college graduate or more), which came from the W1 self-administered questionnaire. Time-variant demographic characteristics included W2-W1 changes in income (no reported change vs. increase vs. decrease, by 10k USD increments), employment status (no change vs. work more [switching from retired/unemployed to part-time or full-time; or switching from part-time to full-time] vs. work less [switching from full-time to part-time or retired/unemployed; or switching from part-time to retired/unemployed]), and number of vehicles in household (24). Data on changes in attitudes and beliefs about PA (PA perceptions) between W1 and W2 came from the questionnaires. We used 38 items in 5 separate domains: self-confidence for moderate PA (3 items); enjoyment of moderate PA (3 items); perceived benefits of PA (10 items); perceived barriers to PA (16 items); and social support for PA from family and friends (6 items). Responses were on a 5-level Likert scale (e.g., 1=strongly disagree, ... , 5=strongly agree) and response values were averaged within each domain. Models included differences in PA perception values between waves.

Built Environment

Built environment characteristics were included as control variables because of the known influence of the home neighborhood built environment on walking (9, 25). Factors affecting walkability may confound the link between changes in walking and total PA (26). Participants' home addresses from the survey were geocoded to the rooftop level using King County, WA address point GIS data within ArcGIS 9.3.1 (ESRI, 1999). Four built environment variables were selected to measure neighborhood walkability conditions within an Euclidean distance 833 m of the participants' homes (27): residential density; employment density (25, 28, 29); street intersection density (29, 30); and area percent of neighborhood clusters of commercial destinations (31). To minimize the effect of multicollinearity, we generated a correlation matrix of these variables, which led to including only residential density in the analyses due to its strong correlation with all other built environment variables (minimum $\rho = 0.61$) (32). Residential density has been widely used in many walkability studies, has shown consistent association with walking, and is easy to interpret (7, 25).

Analysis

Within-participant changes in PA by type between the two waves (W2-W1 changes) were first examined using paired *t*-tests and Cohen's *d*. Cohen's *d* values of 0.2, 0.5, and 0.8 are considered to be a small, moderate, and large effect, respectively (33). Separate linear regression models were developed for objective and subjective data. Using objective data, Model 1A examined the effect of changes in total walking, and Models 1B and 1C analyzed utilitarian and recreational walking, respectively. In models using subjective measures, walking data included total (Model 2A), transportation (Model 2C), job-related (Model 2D), and recreation walking (Model 2E). Transportation and job-related walking were combined as utilitarian walking in Model 2B. Adjustment for W2-W1 changes of time-variant and W1 time-invariant control variables were made in both sets of models. In the model results, a coefficient < 1 was interpreted as reflecting a substitution effect and $= 1$ as an additive effect on total PA.

For Models 1A, 1B, and 1C, we used PA measurements calculated from the 500 cpe cut point. Next, we applied PA measurements from other cut points (600 to 1,000 cpe) to test if different cut points affected analysis results. Statistical significance level was set to 0.05. Analyses were conducted using R version 3.1.1.

Results

A total of 21,062 address-matched phone numbers was sampled and were attempted for contact and about 6% were eligible and expressed an interest in participate. Of the initial 701 study enrollees in W1, 651 provided data that met the initial screening criteria. While 501 participants remained in W2 (retention rate 77%), the final study sample was determined as 437 participants after the second screening, excluding participants with changed residence addresses between waves (n=46), missing survey data (n=12), or daily objective or subjective PA > 4 hrs in either wave (n=6). There were 2,943 person-days in W1 and 2,908 person-days in W2 (mean 6.7 days per participant for both waves). The sample had an average age of 51.3 years, 64.5% were female, 83.1% were non-Hispanic white, 76.9% had completed college or higher education, 44.4% had a household income between 50k and 100k USD, and 78% were employed, as reported at W1 (Table 1). Between W1 and W2, 50.1% of the sample experienced no change in household income (±10k USD) and 76.7% had no employment status change.

Objective data showed participants had a total walking mean of 26.0 min per day at W1 and a significant average decrease of 4.0 min at W2. The effect size was small (Cohen's $d=0.18$) (Table 2). Participants had an objective total PA mean of 39.4 min at W1 and a significant average decrease of 5.2 min at W2. The effect size was also small (Cohen's $d=0.18$). Utilitarian walking decreased significantly with a small effect size. On the other hand, recreational walking did not change significantly over time. Table 3 shows objective PA measurements when different cut points were used to identify PA bouts. Obviously, higher cut points yielded fewer PA minutes per day.

Participants reported significantly more PA time than was measured objectively at both waves (paired t -test $p<0.001$). The effect sizes of these differences were moderate (Cohen's $d=0.27$ at W1 and 0.41 at W2). No significant changes were found in subjective total PA or any types of reported walking or PA perceptions over time.

Table 4 shows regression model results using objective measures of PA and walking. A 1-min W2-W1 increase in in total walking or in utilitarian walking was significantly associated with a 1-min W2-W1 increase in objective total PA when including all other variables, indicating an additive effect (Model 1A and Model 1B). In contrast, a 1-min W2-W1 increase in recreational walking was significantly associated with a 0.6-min W2-W1 increase in total PA, suggesting that recreational walking had a substitution effect on total PA (Model 1C). R^2 values of 0.51 and 0.44 for Models 1A and 1B, respectively, were substantially higher than that in Model 1C ($R^2 = 0.08$). When PA measures from different accelerometer cut points were used, coefficients of walking in the models were very similar and they were all statistically significant. For the cut points of 600–1,000 cpe were used, total walking coefficients in Model 1A ranged from 0.97 to 0.99; utilitarian walking

coefficients in Model 1B were 0.97; and recreational walking coefficients in Model 1C ranged from 0.61 to 0.70 (all $p < 0.001$).

Table 5 shows regression model results using subjective measures of PA and different types of walking (Models 2A through 2E). All models estimated that a 1-min W2-W1 increase in total walking or other types of walking were significantly associated with an increase of more than 1 minute W2-W1 change in total PA, indicating an additive effect of walking on total PA. Unexpectedly, having more household vehicles in W2 than W1 was associated with an increase in total PA, when holding the amount of total walking or of walking in any of the walking types constant. R^2 values ranged between 0.14 and 0.36.

Discussion

The present study is among the first to use a longitudinal design and both objective and subjective PA measurements to examine the relationship between changes in walking and PA. Findings clearly indicate that increases in total or utilitarian walking were linked with commensurate increases in total PA. Measured either more objectively through the integration of device-based and travel diary measurement or by direct self-report, total walking or utilitarian walking was shown to have an additive and not a substitution effect on total PA. The estimates for walking in Models 1A and 1B approximate 1, thus providing evidence that total and utilitarian walking resulted in a net additive increase in total PA without bringing a synergistic effect on total PA. The conclusion was robust regardless of accelerometer cut points ranging from 500 to 1,000 counts per 30-sec epoch.

Similar additive or lack of substitution effects were detected in previous studies looking at specific types of PA (10, 11, 34). Studies found that changes in self-report measures of walking for commuting to and from work had an additive effect on self-reported total PA (10, 11). Another study found that transit users increased their PA only on days they used transit, through walking that happened close in time to transit trips. On non-transit days, participants had less overall PA, indicating no substitution of transit-related walking with other types of PA (34). By examining total walking as well as various types of walking and by measuring activity both objectively and subjectively, the present study offers convincing evidence of the additive effect of both total and utilitarian walking on overall PA.

The results suggest that PA promoting interventions should focus on utilitarian or transportation walking and not solely on recreational walking in order to effectively increase total PA. Models of utilitarian or transportation walking provided robust evidence for an additive effect, while the effects of recreational walking were mixed: objectively measured recreational walking showed a substitution effect but self-reported recreational walking did not. Further, public health proponents focusing on promoting utilitarian or transportation walking may partner with the transportation sector to complement their programs with parallel improvements to active and public transit infrastructure and services (34, 35), with employee subsidies for non-car commuting (1), and with other incentives to use active travel at work sites and schools (36).

The only mixed results were found with recreational walking. This might be related to over-estimating self-reported recreational walking and PA. Participants who increased recreational walking, reported a 150% synergistic increase in total PA (coefficient=1.5). In contrast, objectively measured data showed an opposite outcome, a substitution effect. This might be explained by the biased, inaccurate classification of self-reported walking types (13, 25) or the over-estimation of recreational PA (37). Further studies on the contribution of recreational walking to total PA are needed.

Capturing behavior from both objective and subjective angles is a strength of this study. However, defining, measuring, and classifying specific behaviors in free-living conditions is not simple (12, 38). While objectively measured PA data are more accurate than self-reported data, the former measurement framework lacks the contextual information (i.e. PA types and classes of walking) that the latter provides (15). In this study, the two data types complemented each other and helped produce robust and reliable results on the additive effect of walking on PA. Using both objective and subjective data allow this study's results to be comparable with most other studies using either measurement method. Participants in the sample had significant average decreases in objective total walking (−4.0 min) and total PA (−5.2 min) over the 2-year observation interval. The effect sizes in PA changes were small ($d < 0.2$) as only about a third of the participants (37.5%) increased their objectively measured total PA. Reasons behind the decrease are not clear. None of the demographic variables (age, sex, race/ethnicity, income, education, employment status, and number of vehicles) were associated with the change (data not shown). Among comparable longitudinal studies that reported sample mean PA changes, one study from Scotland ($n=9,542$) reported an overall decrease in subjective total PA over a 3-year period (39). An English study ($n=71$) reported no significant changes in objective total PA over a 2-year period in adults (11). Another US study ($n=537$) showed a slight yet significant increase in objective total PA over a 1-year period (40).

Our data showed that participants who reduced the number of household vehicles had decreased subjective total PA when holding total walking constant. The transportation literature has shown that the number of household vehicles is an important predictor of walking (24), suggesting that this finding may contradict prior studies. In fact, the finding may make sense because when total walking is held constant, a decrease in total PA will necessarily come from a decrease in nonwalking PA. Having fewer vehicles could possibly reduce nonwalking PA (e.g., gym workouts requiring driving to and from gym), especially in car-dependent environments, where carless participants may have limited opportunities to be active. One study found that older adults with 0–1 household vehicles were less likely to achieve sufficient moderate or vigorous PA than those with 2 or more vehicles (OR=0.55, 95% CI: 0.39–0.78) (41). Another study found that older driving adults had 7.2 min more daily average accelerometer-measured moderate or vigorous PA than nondriving older adults (42). However, the association was not significant when walking and PA were measured objectively. Further investigations are needed.

We chose a 30-sec interval and epoch to collect simultaneous high-resolution GPS and accelerometer data, respectively, for 7-day observations within the devices' battery life capability. Because different epoch lengths may affect PA estimates (43), our findings may

not be perfectly comparable to other studies with different epoch lengths. We selected 500 cpe for the PA bout detection cut point to include casual walking. The cut point is lower than those in some studies (44, 45) while moderate PA cut points vary across studies and populations (17, 46). However, the conclusion of the no substitution effect did not change when we raised cut point up to 1,000 cpe, which is nearly equivalent to those in the aforementioned studies (44, 45).

Generalizability of our findings may be limited. First, the study sample is representative of the region. When the sample's demographics were compared to the regional data from the 2005–2007 American Community Survey 3-Year estimates, the study sample had a higher proportion of middle-aged group (65.2% in the sample vs. 47.6% in the region), of non-Hispanic white (83.1% vs. 75.5%), and of middle income between 50k–100k USD (44.4% vs. 33.6%) and a lower proportion of full-time employees (52.6% vs. 63.9%). However, our study intended to focus on urban populations who have viable options of walking and transit services, not on general areas. Second, we recruited participants who had been living at their address for at least 1 year at W1 and who stayed at the same address for another 1–2 years at W2. This may exclude socioeconomically disadvantaged populations who needed to move frequently. Longitudinal data collection possibly excluded unhealthy participants. In the current longitudinal analysis, out of 651 participants who returned valid data at the first screening, 214 were excluded for invalid data or dropouts and 437 were entered in the final sample. The two groups were significantly different. The odds ratios for being in the final sample group for participants being non-Hispanic white, having a household income 50k USD, and having a Body Mass Index value $< 25\text{kg/m}^2$, compared to those who were not, were 1.75, 2.33, and 1.52, respectively.

Lastly, we changed measurement devices between W1 and W2. New accelerometers and GPS logger models were selected for the additional information they provided (e.g., inclination from accelerometer) and for their longer battery life. We considered potential issues in data comparability from the two sets of devices to be minimal. Internal studies determined that the GPS data collected from the two devices were comparable. Similarly, others have reported that accelerometer data from the two devices were also comparable (47).

In summary, we could not find evidence of a substitution effect between changes in walking and total PA. Both objective and subjective data confirmed additive effects in which increases in walking can contribute to an overall increase in total PA, thereby justifying the effectiveness of promoting walking as a means to obtain more PA.

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Table 1

Sample characteristics at W1 and changes at W2

Variables	W1 Measurements		W2 Measurement Changes	
	Count	(%)	Count	(%)
Age	Age < 40	89 (20.4)		
	Age 40 to < 65	285 (65.2)		
	Age 65	63 (14.4)		
Sex	Male	155 (35.5)		
	Female	282 (64.5)		
Race/ethnicity	Non-Hispanic white	363 (83.1)		
	Other ethnic	72 (16.5)		
	NA	2 (0.4)		
Education	Some college or below	101 (23.1)		
	College graduate or higher	336 (76.9)		
Employment status	Full-time	230 (52.6)	No change	199 (86.5)
			Work less	22 (9.6)
			NA	9 (3.9)
	Part-time	111 (25.4)	No change	74 (66.7)
			Work more	20 (18.0)
			Work less	9 (8.1)
	Retired/unemployed	85 (19.5)	NA	8 (7.2)
			No change	62 (72.9)
			Work more	10 (11.8)
Household Income	<50k USD	133 (30.4)	NA	13 (15.3)
			No change or ±10k USD	66 (49.6)
			Increase by > 10k USD	38 (28.6)

Variables	W1 Measurements	Count	(%)	W2 Measurement Changes	Count	(%)
Number of vehicles per household	50k to <100k USD	28	(21.1)	Decrease by > 10k USD	1	(0.7)
				NA		
		63	(32.5)	No change or ±10k USD		
				Increase by > 10k USD		
				Decrease by > 10k USD		
	100k USD	90	(89.1)	NA	5	(2.6)
				No change or ±10k USD		
	NA	11	(10.9)	Decrease by > 10k USD		
		9	(2.1)			
Residential density	Mean=20.0 units/ha SD=14.1 units/ha	362	(82.8)	No change		
				Increase	34	(7.8)
				Decrease	39	(8.9)
				NA	2	(0.5)

Table 2

PA measurements and W2-W1 changes

Variables	Wave 1		Wave 2		Within-participant W2-W1 diff.		Paired <i>t</i> -test <i>P</i>	Cohen's <i>d</i> Effect size
	Mean	(SD)	Mean	(SD)	Mean	(SD)		
<u>Objectively measured</u>								
Total walking	26.0	(23.2)	22.0	(20.9)	-4.0	(19.1)	<.001	0.18
• Utilitarian walking	21.3	(21.4)	17.9	(18.6)	-3.4	(17.8)	<.001	0.17
• Recreational walking	4.7	(9.1)	4.0	(8.7)	-0.6	(9.1)	.144	0.07
Total PA	39.4	(28.9)	34.2	(27.6)	-5.2	(26.4)	<.001	0.18
<u>Subjectively measured (IPAQ)</u>								
Total walking	15.4	(17.2)	14.3	(15.1)	-1.1	(19.8)	.237	0.07
• Utilitarian walking	10.4	(14.7)	9.5	(12.8)	-0.9	(16.7)	.255	0.07
- Transportation walking	5.7	(7.1)	5.4	(6.3)	-0.3	(8.2)	.466	0.04
- Job-related walking	4.7	(12.4)	4.1	(11.2)	-0.6	(14.2)	.358	0.05
• Recreational walking	5.1	(7.5)	4.8	(6.1)	-0.2	(8.6)	.607	0.03
Total PA	48.5	(37.5)	48.1	(39.4)	-0.4	(40.7)	.849	0.01
<u>PA perceptions</u>								
Self-confidence for moderate PA	4.0	(0.9)	4.0	(0.9)	0.0	(0.8)	.265	0.04
Enjoy moderate PA	4.3	(0.8)	4.3	(0.9)	0.0	(0.8)	.966	0.00
Benefits of regular PA	4.2	(0.6)	4.2	(0.6)	0.0	(0.5)	.444	0.03
Barriers to regular PA	2.1	(0.7)	2.2	(0.7)	0.0	(0.5)	.868	0.01
Social support from family and friends	2.3	(0.9)	2.3	(0.9)	0.0	(0.7)	.638	0.02

Table 3

PA measurements using different accelerometer cut points

Objective PA measurements		Cut point used to identify PA bouts [counts per 30s epoch]					
		500	600	700	800	900	1,000
<u>Wave 1</u>							
Total walking	[min/d]	26.0	25.1	23.7	22.4	21.2	20.0
• Utilitarian walking	[min/d]	21.3	20.5	19.4	18.2	17.1	16.1
• Recreational walking	[min/d]	4.7	4.6	4.4	4.2	4.1	3.9
Total PA	[min/d]	39.4	36.8	33.4	30.5	28.0	25.8
<u>Wave 2</u>							
Total walking	[min/d]	22.0	21.1	20.0	19.0	17.9	16.8
• Utilitarian walking	[min/d]	17.9	17.2	16.2	15.4	14.5	13.5
• Recreational walking	[min/d]	4.0	3.9	3.7	3.6	3.4	3.3
Total PA	[min/d]	34.2	32.0	28.9	26.5	24.3	22.3

Table 4

Model estimating W2-W1 changes in total PA using objective data

Y=W2-W1 total PA (objective)	Model 1A X= W2-W1 total walking			Model 1B X= W2-W1 utilitarian walking			Model 1C X= W2-W1 recreational walking		
	Coeff	SE	P	Coeff	SE	P	Coeff	SE	P
(Intercept)	0.5	4.3	.910	0.4	4.6	.926	0.1	5.9	.985
X	1.0	0.1	<.001	1.0	0.1	<.001	0.6	0.2	<.001
Age									
Age 40 to < 65	0.3	2.7	.914	0.8	2.9	.777	-1.1	3.6	.768
(ref: age < 40)	1.1	3.8	.771	-2.8	4.0	.483	-1.1	5.2	.834
Sex (ref: female)	1.2	2.1	.577	3.0	2.3	.197	-1.7	2.9	.574
Race/ethnicity (ref: other)	2.5	3.0	.412	0.8	3.2	.809	1.2	4.1	.761
Education (ref: some college or below)	0.7	2.5	.770	-0.8	2.6	.747	3.3	3.4	.320
W2-W1 employment change	-6.4	3.8	.094	-6.1	4.0	.133	-8.6	5.2	.099
(ref: no change)	-1.2	4.0	.767	-2.8	4.3	.521	-3.3	5.5	.549
W2-W1 income change	-1.8	2.5	.470	-0.5	2.7	.852	-0.4	3.4	.917
(ref: no change or ± 10 k USD)	-5.5	2.8	.048	-4.8	2.9	.101	-6.4	3.8	.090
W2-W1 number of vehicle	-5.6	4.0	.160	-5.4	4.2	.204	-5.7	5.4	.290
(ref: no change)	-4.4	3.7	.236	-3.5	3.9	.366	-4.1	5.0	.410
Residential density	-0.1	0.1	.194	0.0	0.1	.575	-0.2	0.1	.097
W2-W1 self-confidence in moderate PA	-0.9	1.4	.501	0.6	1.5	.679	0.9	1.9	.645
W2-W1 enjoy moderate PA	-1.1	1.6	.468	-2.1	1.7	.211	-3.6	2.1	.092
W2-W1 benefit of PA	-1.2	2.1	.571	-0.6	2.3	.796	2.0	2.9	.478
W2-W1 barrier of PA	-3.7	2.6	.149	-2.6	2.8	.346	-6.8	3.5	.054
W2-W1 social support for PA	3.1	1.6	.049	3.6	1.7	.029	1.4	2.1	.504
R ²	0.51			0.44			0.08		

bold
P<0.05

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Table 5

Model estimating W2-W1 changes in total PA using subjective data

	Model 2A X= W2-W1 total walking			Model 2B X= W2-W1 utilitarian walking (transportation + job- related walking)			Model 2C X= W2-W1 transportation walking			Model 2D X= W2-W1 job-related walking			Model 2E X= W2-W1 recreational walking		
	Coeff	SE	P	Coeff	SE	P	Coeff	SE	P	Coeff	SE	P	Coeff	SE	P
(Intercept)	2.7	7.1	.699	0.8	7.5	.916	2.8	8.2	.737	0.1	7.9	.991	4.3	8.1	.602
X	1.2	0.1	<.001	1.3	0.1	<.001	1.6	0.3	<.001	1.2	0.1	<.001	1.5	0.2	<.001
Age															
Age 40 to < 65	2.3	4.4	.597	2.5	4.7	.593	2.8	5.1	.580	1.1	4.9	.818	1.0	5.1	.851
Age 65	-0.7	6.2	.910	2.1	6.6	.755	2.8	7.2	.702	-0.1	6.9	.988	-3.4	7.1	.637
Sex (ref: female)															
Male	1.2	3.6	.726	0.7	3.8	.855	0.9	4.1	.834	0.8	4.0	.833	1.7	4.1	.671
Race/ethnicity (ref: other)															
Non-Hispanic white	-1.1	4.9	.830	-1.8	5.2	.737	-4.5	5.7	.428	0.0	5.5	.997	-1.3	5.7	.812
Education (ref: some college or below)															
College graduate or higher	-1.8	4.1	.650	1.0	4.3	.823	4.7	4.7	.321	-0.2	4.5	.968	-0.5	4.7	.918
W2-W1 employment change															
Work more	0.0	6.3	.994	-2.2	6.6	.741	0.7	7.3	.924	-3.5	7.0	.620	1.8	7.2	.802
Work less	-6.9	6.7	.303	-10.7	7.1	.133	-14.1	7.8	.069	-11.6	7.5	.123	-10.2	7.7	.187
W2-W1 income change															
Increase by > 10k USD	3.6	4.1	.388	2.3	4.4	.594	2.9	4.8	.542	3.4	4.6	.466	5.7	4.7	.232
Decrease by > 10k USD	6.6	4.6	.153	4.6	4.8	.345	2.9	5.3	.587	6.1	5.1	.234	7.3	5.3	.166
W2-W1 number of vehicles															
Increase	4.0	6.5	.543	4.1	6.9	.553	6.1	7.6	.421	2.5	7.3	.730	3.9	7.5	.605
Decrease	-12.9	6.1	.035	-13.6	6.5	.035	-16.2	7.0	.022	-15.6	6.8	.022	-17.4	7.0	.013
Residential density															
[unit/ha]	-0.1	0.1	.653	0.0	0.1	.992	-0.1	0.1	.538	0.0	0.1	.881	-0.1	0.1	.380
W2-W1 self-confidence in moderate PA															
[1-5; Likert scale]	1.7	2.3	.454	2.2	2.4	.362	4.1	2.6	.119	1.3	2.6	.606	2.3	2.6	.375
W2-W1 enjoy moderate PA															
[1-5; Likert scale]	0.7	2.6	.776	1.1	2.7	.684	0.0	3.0	.998	2.1	2.9	.476	0.7	3.0	.805
W2-W1 benefit of PA															
[1-5; Likert scale]	2.2	3.5	.536	2.0	3.7	.595	0.5	4.0	.897	2.1	3.9	.598	1.0	4.0	.809
W2-W1 barrier of PA															
[1-5; Likert scale]	-3.5	4.3	.419	-5.0	4.5	.269	-4.5	4.9	.363	-6.7	4.8	.159	-4.6	4.9	.345
W2-W1 social support for PA															
[1-5; Likert scale]	0.5	2.6	.845	1.0	2.7	.717	1.9	3.0	.513	0.0	2.9	.993	0.1	2.9	.967

Y=W2-W1 total PA (subjective)														
Model 2A			Model 2B			Model 2C			Model 2D			Model 2E		
X= W2-W1 total walking			X= W2-W1 utilitarian walking (transportation + job-related walking)			X= W2-W1 transportation walking			X= W2-W1 job-related walking			X= W2-W1 recreational walking		
Coeff	SE	P	Coeff	SE	P	Coeff	SE	P	Coeff	SE	P	Coeff	SE	P
0.36			0.28			0.14			0.21			0.16		
R ²														