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Isotemporal Substitution of Sedentary Behavior and Physical Activity on Function

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Abstract

The amount of time spent in sedentary behaviors (SB) progressively increases with age, while reducing time spent in light (LPA) and moderate-to-vigorous physical activity (MVPA). These trajectories in PA and SB are linked to accelerated reductions in physical functioning.

PURPOSE—To examine the association of substituting SB time with LPA and MVPA on physical function in older adults.

METHODS—Ninety-one older adults (mean age: 70.7 ± 10.2 yr) wore a hip-mounted accelerometer to measure SB, LPA, and MVPA time. Measures of physical function included a 400m walk test (400W), usual gait speed (UGS), and 5-time sit-to-stand (5xSTS), and the short physical performance battery (SPPB). Isotemporal substitution regression modeling was performed to assess the relationship of replacing the amount of time spent in one activity for another.

RESULTS—Replacing 30 $min \cdot d^{-1}$ of SB with LPA was associated with a significant improvement in 400W ($p = 0.0497$), while MVPA resulted in a significant improvement ($p < 0.01$) in 400W, UGS, 5xSTS, and SPPB. Replacing 60 $min \cdot d^{-1}$ of SB with 10 $min \cdot d^{-1}$ of MVPA and 50 $min \cdot d^{-1}$ of LPA was associated with significant improvements in the 400W, UGS, and 5xSTS ($p < 0.05$). Meanwhile, as little as 5 $min \cdot d^{-1}$ of MVPA and 55 $min \cdot d^{-1}$ of LPA was linked to a 78% increased odds of scoring with good function in the SPPB ($p = 0.0247$).

CONCLUSION—Replacing SB with LPA was linked to a significant improvement in the 400W, but not the other brief functional measures. Mixed doses of LPA and MVPA may add flexibility to interventions targeting reductions of SB in older adults for clinically relevant improvements in physical function.

Keywords

sitting; aging; activity monitoring; exercise; physical function

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INTRODUCTION

Physical activity (PA; any bodily movement) and sedentary behavior (SB; a seated/lying activity with an energy expenditure of ≤ 1.5 MET) are identified as key predictors of skeletal muscle atrophy and functional decline with aging (1). Time spent in SB is positively associated with age (2), often including increased durations of time spent in activities like watching television, reading, and computer use in the elderly (3) and has been linked to diabetes (3), cardiovascular disease (4), functional limitations (5), and premature mortality (6). In particular, for every one hour increment in TV watching there is a reported 11% and 18% increased risk for all-cause and cardiovascular disease-related mortality, respectively (7). While the mechanisms linking negative health outcomes to SB are not fully understood, the relationship appears to occur independent of participating in recommended amounts of moderate-to-vigorous intensity physical activity (MVPA) (6, 8), suggesting a distinct physiological pathway from the benefits of the PA to health (9).

Aside from SB, light-intensity physical activity (LPA; e.g., household chores or light walking) and MVPA (e.g., brisk walking, cycling, stairs, or running) make up the remainder of total daily activities and time spent in these activity domains generally decline with age (10). The contribution of LPA to health and functional capacity in older adults is not well established and previously was regarded as an inadequate stimulus to promote health and functioning (11). As SB-related health risks became apparent in the literature the importance of LPA has come into question as a means to replace SB. While the evidence linking LPA to health and functioning is limited, there is preliminary evidence linking LPA with benefits in physical health, such as body mass index (BMI), handgrip strength, and self-reported lower-extremity function (5, 12). Also, LPA may serve as a prerequisite to MVPA participation which is positively associated with improved physical function among older adults (13, 14). However, these MVPA-related benefits may be minimized or canceled out by prolonged bouts of SB suggesting a need to concurrently target and modify SB, LPA, and MVPA behavior (5, 6, 88).

Age-related trajectories in PA have identified that greatest proportion of increased SB comes from loss of LPA and time spent in MVPA is progressively transferred to SB, rather than LPA (15). While discrepancies in the health effects of LPA have been found in previous investigations, these reports may have underestimated the impact of LPA by not measuring the relationship of transferring time spent in one activity to another. Specifically, traditional multivariate regression has been used to isolate the relationship of a single activity (i.e – SB) while adjusting for time spent in another activity (i.e. – MVPA) as a confounding variable, rather than accounting for displaced time. Isotemporal substitution modeling is a novel statistical approach in epidemiology that addresses the more practical question of the potential relationship of replacing time spent in one activity type to time in another activity (16). Isotemporal substitution is particularly valuable in addressing the co-dependence of SB, LPA, and MVPA within a finite amount of time in the day, and the independent and contrasting effects of SB and PA on function (17). Further, only one paper has cited isotemporal substitution with functional outcomes (18) with a paucity of evidence comparing the relationships of LPA and MVPA on health and functioning in older adult populations. Accordingly, the purpose of this study is to identify the relationship of reallocating various time increments of SB, LPA, MVPA with measures of physical performance in community-dwelling older adults.

METHODS

Participants

One hundred and five able-bodied community-dwelling men and women aged 50–90 years from the Greater Milwaukee area were recruited to participate in this observational study. Recruitment strategies included the circulation of flyers in the surrounding community, university buildings, and local senior centers, lab website postings, and informational fall-risk screenings at local Senior Centers and assisted living communities. Participants were excluded if they have had any neurological or functional impairment that would preclude them from participating in physical activity. The study was approved by the University of Wisconsin-Milwaukee Institutional Review Board and informed consent was obtained from all participants in the study.

Overview

Within four weeks of being screened, individuals visited the Physical Activity and Health Research Laboratory on two occasions and the Neuromechanics Laboratory on one occasion. During the first visit anthropometric measurements were obtained and participants were given verbal instruction on how to wear the physical activity monitors. Following a 7-day monitoring period, the participants returned to the university setting to perform a further testing that included the functional performance-based assessments.

Measures

Anthropometrics and body composition—A physician's scale (Detecto, Webb City, IL) and stadiometer (Continental Scale Corporation, Bridgeview, IL) were used to measure body weight and height, respectively, and BMI was calculated ($kg \cdot (m^2)^{-1}$).

Physical activity—A hip-worn accelerometer (Actigraph GT3X+, Pensacola, FL) was worn for seven consecutive days to collect human movement. Study participants were instructed to wear the accelerometer on their right hip for all waking hours. Data was collected at a sampling frequency of 80 Hz with a band pass filter of 0.25–2.5 Hz to include only human ambulatory movement. Raw accelerometer data was collected and analyzed in one-minute epochs using the ActiLife software (Pensacola, FL). Activity cut-points recommended for adults were used to determine SB (< 100 counts per minute), LPA (100–1951 counts per minute), and MVPA (≥ 1952 counts per minute) (19–21) and a wear time classification algorithm (22) was used along with personal logs to determine valid wear time. While accelerometry is a valid and reliable method of measuring SB and PA, there is not a solidified count per minute cut-point for activity intensities in older adults (23). As such it was decided to use the general practice cut-points for all adults in this sample (19).

Physical function—The Short Physical Performance Battery (SPPB) was administered according to the procedures described by Guralnik et al. (24). The SPPB consists of three tasks designed to assess walking speed, ability to rise from a chair, and maintain standing balance. Briefly, walking speed was tested by recording the faster of two trials while performing a preferred and maximal walking speed. Participants were asked to stand-up and sit-down five times as quickly as possible from a straight-backed chair to determine chair rise ability. The time to complete the five repetitions was recorded and assigned a score. Lastly, for balance participants were evaluated on how long they could remain in a full-tandem (toe of one foot directly behind the heel of the other), semi-tandem (toe of one foot even with heel of the other), and side-by-side (heels of both feet even) standing position. The maximum time spent in each position was 10 seconds (s). In the SPPB, a score of 0–6 is designated as a poor performer, a score of 7–9 as a moderate performer, and 10–12 as a good performer. The SPPB has been identified as a valid and reliable measure of functionality and mortality in older adults (25).

The 400-meter walk test (400W) was performed along a pre-determined walking course in a university building corridor covering a distance of 400 meters (m). Participants were asked to complete the test as fast as possible and allowed two opportunities to stop and rest during the test if needed. One trial was attempted by each participant with a researcher recording time to completion with a stopwatch. If the course was completed, the distance was divided by the time to completion to provide a value in $m \cdot s^{-1}$. The 400W has been identified as a valid and reliable measure of physical function in older adults (26).

For usual gait speed (UGS) participants were asked to perform a preferred walking pace across an eight foot course. The faster of the two measurements was recorded and used for analysis. The distance of the course was divided by the time to complete the course providing a recorded measurement in meters per second ($m \cdot s^{-1}$). Walking at a normal pace has been identified as a valid and reliable performance test for determining level of physical function, deterioration and improvement (27).

The five-time sit-to-stand (5xSTS) was used as a performance measure to assess lower leg power and chair rise ability. The participant was asked to stand-up and sit-down five times as quickly as possible from a straight-backed chair. The chair was placed against a wall and the participant was told to fold their arms across their chest. Time to completion of the five repetitions was collected by a researcher using a stopwatch and recorded in seconds (s). The 5xSTS has been identified as a feasible, reliable, and valid measure for falls prediction in community dwelling older adults (11).

Statistical Analysis

Descriptive statistics for continuous and categorical variables were summarized as mean ± standard deviation and frequency and percentages, respectively. An independent samples t-test was used to test for significant differences in participant characteristics based on sex. Associations between the physical activity components and other covariates were assessed using Pearson correlations with statistical significance at $p < 0.05$.

Prior to statistical modeling, the residuals for all functional measures were assessed for normality using the Shapiro-Wilk's test. The 400W and UGS measures did not deviate from normality and thus the multiple linear regression method were used for these measures. However, the results of the Shapiro-Wilk's test indicated that 5xSTS and SPPB measures were not normally distributed. Thus, a natural-log transformation was applied to the 5xSTS measure and multiple linear regression method was used for this transformed measure. Back transformation (e^{β}) of the 5xSTS data was performed to present the geometric mean, standard error, and 95% confidence intervals. Data can be interpreted as a percent change in time to completion (β*100 per 60 minute change). The SPPB was dichotomized by scores of <10 (poor to moderate performers) and scores of 10+ (good performers) and a logistic regression statistic was used to analyze this measure.

Time spent in SB, LPA, MVPA, and total wear time was standardized by dividing the measured time spent in each of these activities by 60 $min{\cdot}d^{-1}$. Three different regression models were used to assess the relationship of SB and PA on function (single, partition, and substitution models). The single-variable model included only one activity variable (SB, LPA, or MVPA) per functional outcome to determine the overall association of each individual activity. The partition model included all activity variables (SB, LPA, and MVPA) into one model for each functional outcome variable to determine independent associations for each activity variable. The substitution model was used to estimate the relationship of substituting 60 $min{\cdot}d^{-1}$ of time spent in one activity with an equal amount of time spent in another activity with total wear time and the remaining activity being held constant. All models were adjusted for age and sex and a p-value criterion of 0.05 to determine statistical significance. Statistical reporting for the simple, partial, and substitution models include adjusted parameter estimates (β), standard errors (SE), and 95% confidence intervals (CI). All analysis was performed using SAS 9.4 (Cary, NC). For more information on how to perform isotemporal substitution modeling and its interpretation, refer to Mekary, Willett, Hu, & Ding 2009 (16).

To better simulate free-living scenarios, a separate isotemporal substitution model was performed for 60 $min{\cdot}day^{-1}$ using mixed redistributions of LPA and MVPA to replace SB. This was performed by redistributing 60 $min{\cdot}day^{-1}$ of SB toward a mixed share of the other two remaining activities (MVPA and LPA) by increments of 5 $min{\cdot}d^{-1}$ (i.e., 0 $min{\cdot}d^{-1}$ MVPA/60 $min{\cdot}d^{-1}$ LPA; 5 $min{\cdot}d^{-1}$ MVPA/55 $min{\cdot}d^{-1}$ LPA; 10 $min{\cdot}d^{-1}$ MVPA/50 $min{\cdot}d^{-1}$ LPA; 15 $min{\cdot}d^{-1}$ MVPA/45 $min{\cdot}d^{-1}$ LPA…60 $min{\cdot}d^{-1}$ MVPA/0 $min{\cdot}d^{-1}$ LPA) while keeping total wear time constant.

Cut-off points of meaningful change (minimal clinical important difference) for 400W and UGS determined based on the relationship between noticeable and beneficial change in perceived function with each specific performance-based measure (28). For 5xSTS, an improvement of 2.3 s is linked to a 49% improvement in self-reported function in vestibular disorders (29) and is represented by a 15.1% improvement completion time in the current sample. Clinical interpretation for SPPB was based on odds ratio of being a poor/moderate performer (< 10) compared to a good performer (≥ 10).

RESULTS

Descriptive Characteristics

Ninety-one individuals (60% female) completed the physical activity monitoring period and performed the physical function assessments. Descriptive results regarding the physical characteristics, PA monitoring, and physical performance tests can be found in Table 1. Approximately 93% of study participants were identified as white and 76% completed college-level education. Sixty-one percent of participants were overweight or obese and DXA imaging identified a significant sex difference in body composition. Other significant sex differences ($p < 0.05$) can be found in Table 1 and include height, weight, leg strength, accelerometer wear time, and steps·day^{-1}.

On average, participants wore the accelerometers for 13.99 ± 0.13 h·day^{-1} with female participants wearing the device significantly longer (30.7 min·d^{-1}, $p = 0.036$). Approximately 63.7% of valid wear time was spent in a SB, 33.4% in LPA, and 2.9% in MVPA with no sex differences. One in four participants met the recommended 150 min·wk^{-1} for MVPA (30).

Associations with Physical Function

Single and partition models—Single-activity, partition, and substitution model parameters are presented in Table 2. Single activity models identified LPA as a significant predictor of 400W ($\beta = 0.064$, 95% CI = 0.013–0.116, $p = 0.015$) and MVPA for 400W (0.407 0.219–0.595, $p < 0.001$), UGS (0.295, 0.146–0.444, $p = 0.0002$), 5xSTS (−4.433, −7.217 – −1.650, $p = 0.001$), and SPPB (3.233, 1.045–5.422, $p = 0.0038$). Lastly, total wear time was a significant predictor of 5xSTS performance (−0.747, −1.444 – −0.050, $p = 0.021$). Partition models presented similar associations for the physical performance measures relative to the single-variable models for activity, with an exception to total wear time.

Substitution models—Overall, substituting daily time spent in SB with either LPA or MVPA resulted in beneficial changes in physical function; however, the magnitude of improvements was greater for MVPA compared to LPA. Substitution models identified that replacing 60 min·d^{-1} of SB time with LPA resulted in a significant improvement in 400W (0.053, 0.000–0.106, $p = 0.0497$). However, a 60 min·d^{-1} increase in LPA alone did not lead to significant change the other three functional measures. When 60 min·d^{-1} of SB time was replaced by MVPA there was a significant improvement in 400W (0.385, 0.198–0.057, $p < .001$), UGS (0.293, 0.142–0.445, $p = 0.0002$), 5xSTS (−4.071, −6.855– −1.288, $p = .0024$), and SPPB (3.197, 0.953–5.442, $p = 0.0054$). All other variations of the activity substitution model can be found in Table 2. Not reported in the results is the output for 30 min·d^{-1} which provide the same statistical significance, but with parameter estimates of a lower magnitude.

Mixed redistribution-substitution models—The associations of mixed redistributions of time spent in LPA and MVPA to replace 60 min·d^{-1} of a SB on 400W, UGS, and 5xSTS can be found in Figure 1a-c and the odds ratios for SPPB in Table 3. In general, the redistribution of time spent in SB toward any mixture of LPA and MVPA tended toward improvements in all functional measures. Meanwhile, each 5 min·d^{-1} increase of MVPA as a representative proportion of total PA to replace 60 min·d^{-1} of SB resulted in greater magnitudes of improvement for all functional measures in a linear fashion.

Specifically, replacing 60 min·d^{-1} of SB with 60 min·d^{-1} of LPA and 0 min·d^{-1} in MVPA showed statistically significant and probable clinically meaningful changes in the 400W

(0.053, 0.000–0.106, $p = 0.0497$). As shown in Figure 1a, each 5 min·d^{-1} increase in time spent in MVPA represented a linear greater magnitude of improvement in the 400W up to 60 min·d^{-1} of MVPA (0.385, 0.094 – 0.198, $p < 0.001$).

For UGS, redistributing 60 min·d^{-1} of SB time with as little as 5 min·d^{-1} of MVPA and 55 min·d^{-1} of LPA was resulted in a statistically significant improvement (0.047, 0.006–0.088, $p = 0.024$). As shown in Figure 1b, every 5 min·d^{-1} increase in MVPA represents a linear increase in magnitude of improvement up to 60 min·d^{-1} of MVPA (0.293, 0.142–0.444, $p < 0.001$).

For 5xSTS, redistributing 60 min·d^{-1} of SB toward 10 min·d^{-1} of MVPA and 50 min·d^{-1} of LPA resulted in a statistically significant improvement (-0.061, -0.109- -0.014, $p = 0.012$). As shown in Figure 1c, every 5 min·d^{-1} increase in MVPA represents a linear increase in magnitude of improvement up to 60 min·d^{-1} of MVPA (-0.260, -0.425- -0.095, $p = 0.002$).

For the SPPB, redistributing 60 min·d^{-1} of SB towards as little as 5 min·d^{-1} of MVPA and 55 min·d^{-1} of LPA was significantly associated with a 78% increased odds of falling into a good function range of 10–12 (1.785, 1.076–2.960, $p = 0.0247$). As shown in Table 3, increasing increments of daily time spent in MVPA represented significantly greater odds of having a score indicating good function with a full redistribution of SB toward 60 min·d^{-1} of MVPA resulting in a 25-fold increased odds (24.469, 2.594–230.781, $p = 0.0052$).

For all performance-based measures, there was a significant detrimental effect when replacing MVPA with any share of LPA or SB ($p < 0.01$).

DISCUSSION

Time spent in MVPA has been consistently linked to physical function while the contributions of LPA are not well established. Findings from this investigation highlight the importance of altering the LPA and SB balance with statistically significant improvements in 400W when replacing as little as 30 min·d^{-1} of SB with LPA. Doubling the LPA substitution to 60 min·d^{-1} was associated with a linear two-fold improvement in 400W resulting in a probable clinically meaningful change. Not all measures of physical performance were as sensitive as the 400W when replacing SB with isolated LPA. However, mixed ratios of time spent between LPA and MVPA to replace SB time may provide effective and feasible approaches to reducing SB time and improving physical function. Replacing 60 min·d^{-1} of SB with a 5-to-1 ratio of LPA-to-MVPA resulted in statistically significant improvements in the remaining performance-based measures. Furthermore, clinically meaningful changes in physical function required a mixture of LPA and MVPA in all physical performance measures, except for 400W when replacing 60 min·d^{-1} of LPA for SB.

These findings are important considering the growing public health concern of an aging older adult population with increased risk of mobility disability, the current SB and PA trends in older adults, and the scarcity of interventions targeting SB in older adults. Older adults accumulate the greatest amount of SB with age-related trajectories leading to reduced time spent in both LPA and MVPA (15). Physical activity presents the strongest overall evidence for combatting physiological decline and the accumulation of comorbidities that are linked with physical functioning (31). Further, these findings highlight the utility of creating flexible PA prescriptions that can use a mixture of various PA intensities while holding clinically relevant performance outcomes in mind. This may be of ultimate importance among an older adult population that lacks the musculoskeletal and cardiopulmonary capacity to perform continuous bouts of MVPA.

Reasons for the discrepancies between the effect of LPA on 400W and other physical performance measures may include the added cardiorespiratory challenge 400W compared to the other brief performance measures. While the SPPB score is predictive of the inability to complete the 400W (32), the 400W has been linked to premature mortality independent of SPPB scores (33) and predictive of medical conditions, falls, medication use, muscle strength, and muscle power among those that scored 10+ in the SPPB (34). The SPPB, UGS, and 5xSTS primarily consist of tasks that focus on balance and lower limb strength necessary to ambulate in brief bouts of < 30 s. In the current study sample, the average time for completing the 400W was approximately 9 min and 20 s with SPPB scores of 10+ performing nearly 2 min faster. These cross-sectional associations indicate that 400W performance may serve as a measure of interest to test the impact of LPA and MVPA to replace SB in moderate and high functioning older adults. Also, LPA may not be an adequate stimulus to preserve the rapid loss of function in late life as indicated by the brief measures, but may be an indicator of continuous ambulatory ability. However, the disability process which includes progressive declines in physical performance is predicted by the accumulation of multiple comorbidities which can be augmented by LPA and/or MVPA (4, 18, 35).

Traditional PA interventions that exclusively focus on increasing MVPA may fail to offset the negative health effects of SB which tends to replace LPA (36). Collectively, the independent health effects of SB and PA on physical function (5), morbidity and mortality (6), and the inability of PA interventions to offset SB time (37) suggest a need for concurrent prescription of SB, LPA, and MVPA. Systematic reviews have identified that SB is a relatively stable behavior that is not subject to change when increasing MVPA, but has the potential to be reduced when specifically targeted (37). Therefore, the transition of an *inactive couch potato* to an *active couch potato* (38) may disregard the potential confounding impact of SB on functional health.

The results from this study may aid the development of effective interventions aimed at reducing SB time and increasing PA time for the purpose of improving physical performance in older adults. The association between functional health and MVPA found in this study are consistent with previous findings using similar population representative surveillance data (5, 15), emphasizing the benefits of MVPA over LPA and SB. However, the complete transfer of an additional 30 or 60 min·d^{-1} of MVPA to replace SB may be impractical for many older adults. Specifically, the discretionary time available to older adults varies depending on socioeconomic status, occupation, and other social circumstances. Also, the heterogeneity in an individuals’ preferences and ability to perform PA of various intensities are key determinants in the selection, initiation, and maintenance of PA as a form of lifestyle change (39). Thus, it is important to consider the impact of all levels of PA to maintain and rehabilitate functioning in older adults. Prolonged bouts of SB often take place in specific domains that may prove difficult to interrupt or replace including television viewing, computer use, and reading. Further, the initiation and successful maintenance of MVPA adoption in older adults has proven to be a formidable task while LPA has been identified as a preferred intensity (40). Therefore, the introduction of a LPA may be a practical and feasible approach to developing interventions to reduce SB.

To our knowledge, only one other study has used isotemporal substitution modeling to measure the association of reallocating SB with various PA intensities on measures of functional performance (17). Traditional multivariate regression models typically provide a regression coefficient per minute in a single activity while adjusting for time spent in activities that are inter-dependent and under the assumption of continuous time. Adjustment for time spent in other activities does not provide an appropriate control for a finite amount of time during waking hours with mutually exclusive activities. In addition to addressing these statistical limitations, the current technique has the advantage of addressing the potential underestimation of health benefits of PA and SB in previous studies by compounding the association of reducing time spent in an activity negatively associated with health and increasing time spent in an activity positively associated with health. While reporting the isotemporal substitution models in 60 min·d^{-1} increments provides immediately interpretable results, the jump to increasing LPA or MVPA by 60 min·d^{-1} may not be an immediately adoptable approach. As a possible introduction and not reported in our results is the output of a 30 min·d^{-1} isotemporal substitution model that reported the same statistical significance, but to lesser magnitude of change. Further strengthening this study is the use of dose-response mixed redistributions of LPA and MVPA to replace SB time. In addition to the strengths listed above, this study is not free of limitations. This study is limited by a relatively small sample size with fairly homogenous demographics. Additional studies and replication in larger and nationally representative samples would be important next steps to corroborate and further this study’s findings.

CONCLUSION

The health benefits of MVPA cannot be overstated, but how an individual spends the rest of the day spent between LPA and SB appears to play a role in determining physical function. Introducing LPA to specifically replace SB, but not MVPA, may serve as a sufficient stimulus to preserve and/or improve physical function in community-dwelling older adults. This emphasizes the need for public health approaches to mutually target SB, LPA, and MVPA when aiming to delay or reverse functional limitations in older adults. Previous investigations using this model have implied the use of doubling time spent in MVPA which may not be a feasible option for many older adults. The ability to mutually prescribe LPA and MVPA to augment clinically relevant changes in physical performance adds flexibility while optimizing interventions focused on clinically relevant changes in physical function.

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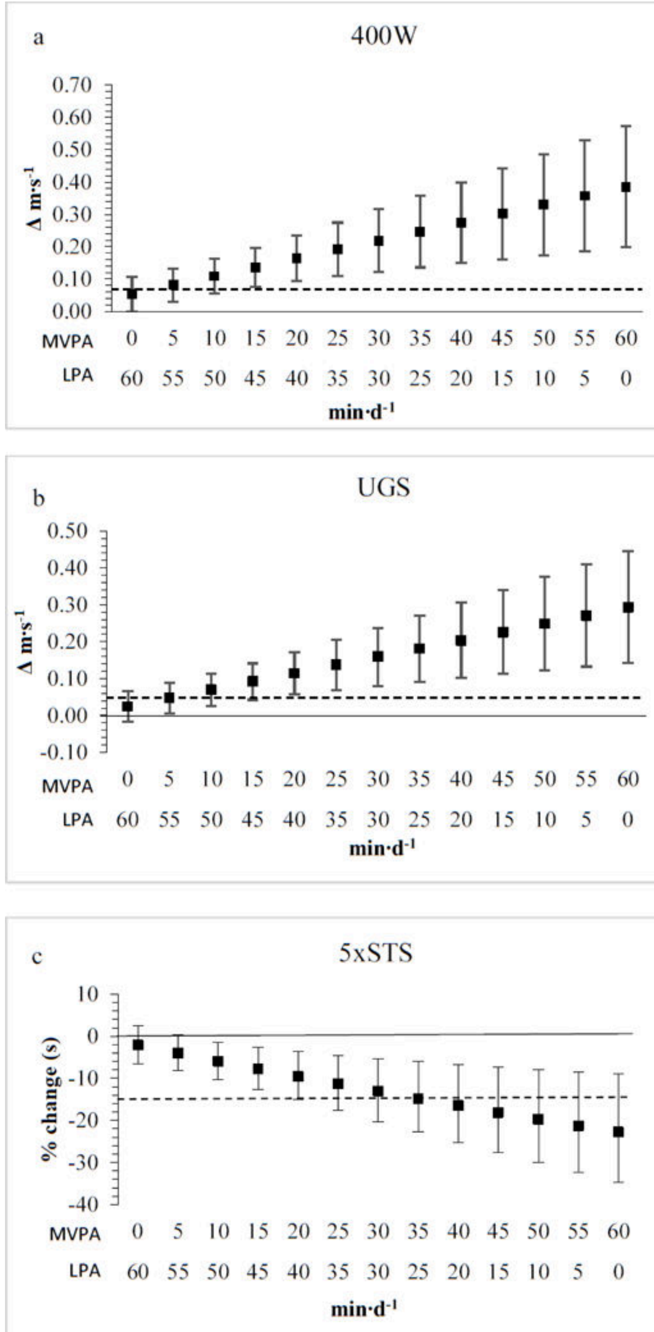

Figure 1.

Figure 1a–c-Substitution regression model for replacing SB with various ratios of LPA and MVPA (0–60 min). For 400W and UGS, values indicate the parameter estimate and 95% confidence intervals adjusted for age and sex. 5xSTS is presented as the geometric mean and 95% confidence intervals and should be interpreted as a percent change in 5xSTS completion time per 60 minute substitution for SB. Reference values for minimum clinically important difference represented by black dashed line: 400W at 0.05–0.075 m·s^{-1} (28); UGS at 0.03–0.05 m·s^{-1} (28). 5xSTS at 15.1% based on an MCID of 2.3 s (29). 400W: 400-meter walk, UGS: usual gait speed, 5xSTS: timed five-time sit-to-stand, SB: sedentary behavior, LPA: light-intensity physical activity, MVPA: moderate-to-vigorous-intensity physical activity, OR: odds ratio

TABLE 1

Descriptive Characteristics

	Total (N=91)		Female (n=55)		Male (n=36)		
	Mean	SD	Mean	SD	Mean	SD	P_{sex}
Age (y)	70.7	10.2	69.4	10.8	72.8	8.6	.271
Height (cm)	166.6	9.1	162.4	7.4	173.7	7.2	<.001
Body mass (kg)	75.6	17.4	71.7	16.9	82.1	16.3	.002
Body mass index kg·m^2-1	27.2	5.7	27.2	6.2	27.2	4.8	.929
400W (m·s^{-1})	1.4	0.3	1.4	0.3	1.4	0.4	.752
UGS (m·s^{-1})	1.1	0.3	1.1	0.3	1.1	0.2	.772
5xSTS (s)	15.2	4.8	15.2	4.3	15.3	5.5	.957
SPPB balance score (0–4)	3.8	0.5	3.7	0.6	3.9	0.3	.063
SPPB chair score (0–4)	2.2	1.1	2.1	1.1	2.2	1.1	.715
SPPB gait score (0–4)	3.8	0.6	3.8	0.7	3.9	0.4	.430
SPPB total score (0–12)	9.8	1.6	9.7	1.7	9.9	1.4	.354
Total Wear Time (min·d^{-1})	844.8	75.8	856.3	67.0	825.6	86.3	.036
SB (min·d^{-1})	536.6	75.7	539.5	63.7	531.8	93.2	.468
LPA (min·d^{-1})	283.1	73.3	290.9	67.1	270.1	82.0	.138
MVPA (min·d^{-1})	25.0	20.9	25.8	22.4	23.7	18.2	.912
Steps (steps·d^{-1})	6343	3950	7229	3486	4858	4279	.036
Time spent in SB (% wear time)	63.7	8.2	63.2	7.3	64.6	9.5	.595
Time spent in LPA (% wear time)	33.4	7.6	33.8	6.9	32.6	8.6	.434
Time spent in MVPA (% wear time)	2.9	2.4	3.0	2.5	2.9	2.1	.626
≥10min MVPA bout (min·d^{-1})	13.8	16.5	15.3	18.5	11.2	12.4	.593
≥20min SB bout (min·d^{-1})	212.9	71.8	206.7	61.5	223.3	86.4	.306
≥150 min·d^{-1} of MVPA (% of participants)	25.3	43.7	31.6	46.9	14.7	35.9	.187

400W: 400-meter walk, 5xSTS: timed five-time sit-to-stand, UGS: usual gait speed, SPPB: short physical performance battery, SB: sedentary behavior (<100 counts·min^{-1}), LPA: light-intensity physical activity (100–1951 counts·min^{-1}), MVPA: moderate-to-vigorous-intensity physical activity (≥1952 counts·min^{-1}), SD: standard deviation. Accelerometer total wear time based on Choi Algorithm (22) and logs.

TABLE 2

Single, partition and substitution model estimates for SB, LPA, MVPA, and Total Wear Time in 60 minute increments

	SB (60 min)				LPA (60 min)				MVPA (60 min)				Total Wear Time (60 min)			
Analysis Method	**β**	**SE**	**Lower 95% CI**	**Upper 95% CI**	**β**	**SE**	**Lower 95% CI**	**Upper 95% CI**	**β**	**SE**	**Lower 95% CI**	**Upper 95% CI**	**β**	**SE**	**Lower 95% CI**	**Upper 95% CI**
400W ($m \cdot s^{-1}$)																
Substitution of activity to replace SB	Dropped				**0.053**	**0.027**	**0.000**	**0.106**	**0.385**	**0.094**	**0.198**	**0.57**	0.003	0.025	-0.047	0.053
Substitution of activity to replace LPA	**−0.053**	**0.027**	**−0.106**	**0.000**	Dropped				**0.332**	**0.098**	**0.136**	**0.528**	**0.056**	**0.028**	**0.002**	**0.111**
Substitution of activity to replace MPVA	**−0.385**	**0.094**	**−0.572**	**−0.198**	**−0.332**	**0.098**	**−0.528**	**−0.136**	Dropped				**0.388**	**0.094**	**0.200**	**0.575**
Partition Models	0.003	0.025	−0.047	0.053	**0.056**	**0.028**	**0.002**	**0.111**	**0.388**	**0.094**	**0.200**	**0.575**	N/A			
Single Activity Models	−0.075	0.024	−0.085	0.010	**0.064**	**0.026**	**0.013**	**0.116**	**0.407**	**0.095**	**0.219**	**0.595**	0.041	0.0025	-0.009	0.090
UGS ($m \cdot s^{-1}$)																
Substitution of activity to replace SB	Dropped				0.025	0.021	−0.018	0.068	**0.293**	**0.076**	**0.142**	**0.445**	-0.008	0.021	-0.050	0.033
Substitution of activity to replace LPA	−0.025	0.021	−0.068	0.018	Dropped				**0.269**	**0.080**	**0.112**	**0.426**	0.016	0.022	-0.027	0.060
Substitution of activity to replace MPVA	**−0.293**	**0.076**	**−0.445**	**−0.142**	**−0.269**	**0.080**	**−0.426**	**−0.112**	Dropped				**0.285**	**0.076**	**0.133**	**0.436**
Partition Models	−0.009	0.035	−0.050	0.032	0.016	0.021	-0.027	0.060	**0.285**	**0.076**	**0.133**	**0.436**	N/A			
Single Activity Models	−0.027	0.019	−0.065	0.011	0.026	0.020	-0.014	0.066	**0.295**	**0.075**	**0.146**	**0.444**	0.013	0.020	-0.026	0.052
5xSTS (% change s) [a]																
Substitution of activity to replace SB	Dropped				−0.334	0.392	−0.1.115	0.446	**−4.071**	**1.400**	**−6.855**	**−1.288**	−0.454	0.383	−1.215	0.308
Substitution of activity to replace LPA	0.334	0.392	−0.446	1.115	Dropped				**−3.737**	**1.454**	**−6.630**	**−0.844**	**−0.788**	**0.403**	**−1.590**	**0.013**
Substitution of activity to replace MPVA	**4.071**	**1.400**	**1.288**	**6.855**	**3.737**	**1.454**	**0.844**	**6.630**	Dropped				**−4.525**	**1.403**	**−7.316**	**−1.734**
Partition Models	−0.454	0.383	−1.215	0.308	−0.788	0.403	−1.590	0.013	**−4.525**	**1.403**	**−7.316**	**−1.734**	N/A			
Single Activity Models	0.092	0.349	−0.602	0.786	−0.622	0.365	-1.349	0.104	**−4.433**	**1.400**	**−7.217**	**−1.650**	**−0.747**	**0.350**	**−1.444**	**−0.050**
SPPB (score: <10 or 10+) [b]																
Substitution of activity to replace SB	Dropped				0.342	0.260	−0.168	0.851	**3.197**	**1.145**	**0.953**	**5.442**	0.188	0.231	-0.264	0.641
Substitution of activity to replace LPA	−0.342	0.260	−0.851	0.168	Dropped				**2.856**	**1.170**	**0.562**	**5.150**	0.530	0.276	-0.012	0.1.071
Substitution of activity to replace MPVA	**−3.197**	**1.145**	**−5.442**	**−0.953**	**−2.856**	**1.170**	**−5.150**	**−0.562**	Dropped				**3.386**	**1.179**	**1.074**	**5.697**
Partition Models	0.188	0.231	−0.264	0.641	0.530	0.276	-0.012	1.071	**3.390**	**1.179**	**1.074**	**5.697**	NA			
Single Activity Models	−0.152	0.193	−0.530	0.226	0.430	0.227	-0.015	0.876	**3.233**	**0.1.117**	**1.045**	**5.422**	0.335	0.203	-0.062	0.733

400W: 400-meter walk, UGS: usual gait speed, 5xSTS: timed five-time sit-to-stand, SPPB: short physical performance battery, SB: sedentary behavior, LPA: light-intensity physical activity,

MVPA: moderate-to-vigorous-intensity physical activity, β: regression coefficient, SE: standard error

[a] Statistical analysis for 5xSTS was performed after a natural log transformation. A back transformation (e^{β}) was performed to obtain the geometric mean presented in the table.

[b] Estimates for the SPPB single, partition, and substitution models were performed using logistic regression to model the log odds ratio of good performers vs poor/moderate. To obtain the odds ratio, the regression coefficient should be exponentiated.

All models are adjusted for age and sex. Values tagged in bold are statistically significant ($p < 0.05$).

TABLE 3

Odds ratio of changing from an SPPB score of low/moderate (<10) to good (10+)

Substituting 60 min·d^{-1} of SB for:					
LPA (min)	**MVPA (min)**	**OR**	**Lower 95%**	**Upper 95%**	**P**
60	0	1.4070	0.8454	2.3418	0.1890
55	5	1.7849	1.0765	2.9595	0.0247
50	10	2.2649	1.2808	4.0052	0.0049
45	15	2.8732	1.4505	5.6915	0.0025
40	20	3.6449	1.5955	8.3267	0.0022
35	25	4.6252	1.7264	12.3912	0.0023
30	30	5.8675	1.8498	18.6113	0.0027
25	35	7.4434	1.9701	28.1224	0.0031
20	40	9.4443	2.0900	42.6774	0.0035
15	45	11.9821	2.2114	64.9229	0.0040
10	50	15.2003	2.3352	98.9395	0.0044
5	55	19.2883	2.4627	151.0662	0.0048
0	60	24.4688	2.5943	230.7811	0.0052

SPPB: short physical performance battery, SB: sedentary behavior, LPA: light-intensity physical activity, MVPA: moderate-to-vigorous-intensity physical activity, OR: odds ratio