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Sedentary behavior patterns over 6 weeks among ambulatory people with stroke

Emily A. Kringle, PhD, OTR/L[a], **Elizabeth R. Skidmore, PhD, OTR/L**[b], **Lauren Terhorst, PhD**[b], **Joy Hammel, PhD, OTR/L**[c], **Bethany Barone Gibbs, PhD**[d]

[a]Division of Academic Internal Medicine and Geriatrics, College of Medicine, University of Illinois at Chicago, 1747 W Roosevelt Rd, Chicago, IL 60608

[b]Department of Occupational Therapy, School of Health and Rehabilitation Sciences, University of Pittsburgh, 100 Bridgeside Point, Suite 350, Pittsburgh, PA 15260

[c]Department of Occupational Therapy, College of Applied Health Sciences, University of Illinois at Chicago, 1919 W. Taylor St., MC811, Chicago, IL 60612

[d]Department of Health and Human Development, School of Education, University of Pittsburgh, 220 Oak Hill, Pittsburgh, PA 15260

Abstract

Objective: To describe patterns of sedentary behavior over 6 weeks among ambulatory people with subacute and chronic stroke.

Design: Observational longitudinal study with assessments at baseline (T0) and week 6 (T1).

Methods: Community-dwelling people with stroke (n=39) pooled from 2 studies who were ≥18 years of age were assessed for sedentary behavior at 2 timepoints (T0, T1). Sedentary behavior was measured with the activPAL micro3 following a 7-day wear protocol to obtain mean daily: total sitting time, sitting time accumulated in bouts ≥30 minutes, number of sit-to-stand transitions, and fragmentation index (sit-to-stand transitions/total sitting hours). Paired samples *t*-tests were used to calculate mean group differences in sedentary behavior metrics between T0 and T1 (α=.05). Cohen's *d* was calculated to describe the magnitude of within-person change between T0 and T1.

Results: There were no statistically significant within-person differences between T0 and T1 on mean daily sitting time (Cohen's $d=-0.21$, $p=.19$), sitting time accumulated in bouts ≥30 minutes ($d=-0.27$, $p=.11$), number of sit-to-stand transitions ($d=-0.02$, $p=.53$), or the fragmentation index ($d=-0.11$, $p=.92$).

Conclusions: Sedentary behavior metrics were stable over 6 weeks. The number of sit-to-stand transitions per day and the fragmentation index appeared to be the most stable indicators over 6 weeks. Future research should confirm these findings and identify correlates of sedentary behavior among people with stroke.

Corresponding Author: Emily A. Kringle, PhD, OTR/L; kringle@uic.edu.

Keywords

sedentary lifestyle; lifestyle; rehabilitation; physical activity; longitudinal study

Introduction

Sedentary behavior is emerging as a risk factor for poor health outcomes distinct from insufficient physical activity. High levels of sedentary behavior are associated with elevated risk for cancer, cardiovascular disease, diabetes, and mortality [1–3]. Cardiovascular disease and uncontrolled diabetes place people at risk for primary and recurrent stroke [4,5]. Physical activity engagement is routinely recommended to reduce recurrent stroke risk among the 80 million survivors of stroke globally [6,7]. Guidelines for healthy adults recommend engaging in moderate-to-vigorous physical activity *and* minimizing sedentary behavior to improve cardiovascular and cardiometabolic health [8–12]. Interventions that are designed to reduce post-stroke sedentary behavior are emerging [13–15]. To adequately interpret sedentary behavior outcomes of these interventions, *reduced sedentary behavior* must be clearly conceptualized. Intervention studies that employ a pre-post-intervention design assume that sedentary behavior is stable over time. To precisely interpret sedentary behavior metrics associated with interventions, we must understand naturally occurring patterns of sedentary behavior among people with stroke.

Sedentary behavior is defined as waking time spent in a seated, reclined, or lying position during which activities demand less than or equal to 1.5 times the resting metabolic equivalent (MET) [16]. People with stroke spend 8.6 to 11.3 hours per day (60% to 80% of waking hours) sedentary [17–19], which is higher than the estimated 5.5 to 6.4 hours per day reported in healthy adults [20–22]. In addition to reducing the overall amount of sedentary time, modifying patterns of sitting were also associated with positive health outcomes [11]. Sedentary behavior metrics that are used among healthy older adults and adults with diabetes, multiple sclerosis, and obesity include total sitting time, total sitting time accumulated in prolonged bouts (i.e., bouts of at least 30 minutes), number of sit-stand transitions, and the number of sit-to-stand transitions per hour of sitting (fragmentation index) [23–25]. Few studies have reported these metrics in stroke. Among those that have, there is inconsistency in the specific metrics used to describe sedentary behavior. Descriptive studies have reported high levels of total sitting time and low levels of fragmentation at 6 months and 12 months post-stroke [21,26,27]. Although intervention studies reported on change in the amount of sitting time accumulated in prolonged bouts, no known descriptive studies have reported on stability or variability of this metric. The relationships among these sedentary behavior metrics remain unclear, limiting comparison across studies that report disparate metrics. Furthermore, no studies have reported on stability or variability of sedentary behavior metrics over time periods aligned with sedentary behavior and physical activity intervention durations (4 to 12 weeks) after stroke [13–15].

The aims of this secondary analysis are to: 1) describe the degree of stability of sitting time over 6 weeks among community-dwelling people with stroke not engaged in sedentary behavior intervention, and 2) describe the degree of stability of sedentary behavior fragmentation over 6 weeks among these same community-dwelling survivors of stroke. An exploratory aim of this study was to explore associations among sedentary behavior metrics.

Methods

Data were collected as part of two studies. Study one was a descriptive study. Study two was a nonrandomized single arm intervention study that had a delayed baseline design. The present analysis includes baseline data that were collected prior to the delivery of intervention. Data collection occurred between February 2018 and November 2018. In both studies, sedentary behavior metrics were measured at study enrollment (T0) and 6 weeks later (T1). This time frame was selected to align with the duration of existing interventions and reflects common intervention durations (4 to 12 weeks) [13,14,28]. In both studies, participants did not interact with the research team between timepoints. The descriptive study was completed at the end of T1. The intervention study proceeded with a behavioral intervention and follow-up assessments, described elsewhere [28]. Data from these studies were pooled to describe sedentary behavior metrics in a larger sample. Both studies were approved by the University of Pittsburgh institutional review board and conducted in compliance with the Helsinki Declaration. Participants provided informed consent.

In both studies, participants were recruited from the community and included if they: 1) had a history of stroke, and 2) were ≥18 years of age, and 3) resided within 100 miles of our research institution. Participants were excluded if they: 1) had severe communication impairment (Boston Diagnostic Aphasia Examination score ≤1) [29], 2) were receiving cancer treatment, 3) were diagnosed with a neurodegenerative disorder, or 4) were currently admitted to a hospital, inpatient rehabilitation center, or skilled nursing facility. Additional inclusion criteria for the intervention study were that participants: 1) self-reported ≥ 6 hours of daily sitting on the Sedentary Behavior Questionnaire [30], and 2) were ambulatory without physical assistance from another person. Additional exclusion criteria for intervention study participants were: 1) current participation in outpatient or home health occupational, physical, or speech therapy, and 2) current major depressive disorder, psychiatric condition, or substance abuse (Patient Health Questionnaire-9, PRIME-MD/Mini International Neuropsychiatric Interview) [31,32].

Screening and study assessments were conducted by a trained research assistant who had prior experience assessing people with stroke. Clinical descriptors were assessed at T0. Sedentary behavior metrics were measured over 7 days at T0 and T1.

Clinical descriptors.

Clinical descriptors included motor function, cognitive functions, mood, mobility, and difficulty completing activities of daily living (ADLs). The Stroke Impact Scale, Physical Function Subscale (SIS-PHYS), Mobility Subscale (SIS-MOB), and ADL/IADL Subscales (SIS-ADL) are self-report assessments of motor function, mobility, and ADL function, respectively. On the SIS-PHYS, participants rate the amount of strength in their affected arm, hand/wrist, leg, and foot/ankle on a 1 to 4 Likert-type scale. On the SIS-MOB and SIS-ADL, Participants rate the amount of difficulty they experience on 9 mobility tasks and 10 common ADL tasks using a 1 (not difficult at all) to 5 (extremely difficult) point Likert-type scale. Scores for each subscale are summed and converted to a 0 to 100 scale, in which high scores indicate high strength or function. The Stroke Impact Scale has acceptable psychometric properties for characterizing post-stroke physical, mobility, and ADL/IADL function [33]. The NIH Toolbox-Cognition Battery is a standardized performance-based measure of language, attention, memory, executive functions, and visuospatial skills [34]. A composite T-score (population M=50, SD=10) describing cognitive function was derived using the NIH Toolbox software [35]. The Patient Health Questionnaire-9 (PHQ) is a 9-item questionnaire with good reliability and validity for assessing depressive symptoms based on the DSM-IV criteria for major depressive disorder [31]. Participants rank the frequency of depressive symptoms within the past 2 weeks on a 0 (not at all) to 3 (nearly every day) scale. Scores range from 0 to 27, with high scores indicating high levels of depressive symptoms.

Sedentary behavior metrics.

Sedentary behavior metrics were assessed using the activPAL micro3 (Pal Technologies, Glasgow). This device (2 cm X 4 cm X 1 cm, 10 grams) provides a valid and reliable measure of time spent in sitting/reclined/lying or upright postures and counts of sit-to-stand transitions among survivors of stroke [36]. Default device settings were used. Participants wore the device 24 hours per day for 7 days during T0 and T1. The device was waterproofed and adhered to anterior aspect of the participants' thigh (non-stroke side). Participants documented sleep and non-wear time using a diary. Data were uploaded using activPAL3 software (v. 7.3.28, Pal Technologies, Glasgow). Sleep time was removed using a diary-informed approach (see supplementary materials) [37]. Days were considered valid if the monitor was worn during all waking hours. The following daily variables calculated: 1) total sitting minutes, 2) prolonged sitting minutes accumulated in bouts of ≥30 minutes, 3) number of sit-to-stand transitions, 4) fragmentation index (sit-to-stand transitions/total sitting hours) [21,23], and 5) daily waking minutes. Thirty minutes was selected as the cut point defining prolonged sitting because this was used in existing stroke studies [13,28]. Daily total sitting minutes, daily prolonged sitting minutes, and daily number of sit-to-stand transitions were standardized to account for within-person variability in waking time. The fragmentation index does not directly co-vary with waking time and, therefore, not adjusted. The daily mean (across 7 days) was calculated for each metric (daily total sitting minutes, daily prolonged sitting minutes, number of sit-to-stand transitions, and fragmentation index) at T0 and T1.

Data analysis.

SPSS Statistics for Windows, version 26 (IBM Corp., Armonk, N.Y., USA) was used for all statistical analyses. For all analyses, α=.05. Data were screened for validity. Prior to pooling the samples, between-group differences in baseline characteristics were identified using independent samples *t*-test or χ^2 tests. activPAL data were also screened for validity. Participants with ≥4 days of valid data at T0 and T1 were retained [36]. The Shapiro-Wilk test was used to assess normality. Paired samples *t*-test (or Wilcoxon Signed Rank Test) were used to assess within-person differences in mean daily total sitting minutes, mean daily prolonged sitting minutes, mean daily count of sit-to-stand transitions, and mean daily fragmentation index between T0 and T1. Cohen's *d* effect sizes were computed to describe the magnitude of within-person changes over time. Effect sizes were interpreted as follows: negligible (d = 0.0 to 0.1), small (d = 0.2 to 0.4), moderate (d =0.5 to 0.6), large ($d \geq 0.7$) [38]. Mean change scores and 95% confidence intervals were computed. To explore the associations among sedentary behavior metrics, the magnitude and direction of Pearson's r (or Spearman's *rho*) were examined within T0 and T1 individually. Results are reported in alignment with the STROBE Guidelines.

Results

Participants.

Forty-one participants were enrolled and 2 were excluded from the analyses because they had fewer than 4 valid days of data at one or more time points. Remaining participants wore the activPAL during all waking hours on 5 (n=1), 6 (n=5), and 7 (n=33) days of monitoring during T0 and 4 (n=1), 6 (n=4), and 7 (n=34) days of monitoring at T1. The samples differed in age, gender distribution, and stroke chronicity. Similarities across measures of function and baseline similarities in outcomes of interest supported pooling the samples. Participants had an average age of 66.3 (range=36 to 89) years and 41% were female. This sample represented a range of chronicity (3 months to 180 months) and included people with ischemic (82%) and hemorrhagic (18%) stroke. The distributions of motor, cognitive, mood, mobility, and self-care abilities by sample (intervention and descriptive) and in the pooled sample are reported in Table 1. Baseline sedentary behavior metrics were comparable across samples. The intervention sample had approximately twice the proportion of females and shorter stroke chronicity than the descriptive sample.

Sedentary behavior metrics.

The unadjusted group mean of daily total sitting time was 704.8 minutes at T0 and 690.3 minutes at T1. The unadjusted group mean of daily prolonged sitting time was 450.3 minutes at T0 and 430.1 minutes at T1. The unadjusted group mean number of daily sit-to-stand transitions was 47.9 transitions at T0 and 47.0 transitions at T1. The group mean fragmentation index was 4.4 bouts per hour at T0 and 4.3 bouts per hour at T1.

Mean within-group differences in sedentary behavior metrics.

Data were normally distributed for all sedentary behavior metrics except prolonged sitting time. Paired samples t-tests were used to assess mean differences on all normally distributed sedentary behavior metrics, and Wilcoxon Signed Rank Test was used to assess mean differences in prolonged sitting. There were no statistically significant differences in total sitting time or prolonged sitting time between T0 and T1 (Table 2). After adjusting for waking time, participants had 712.1 (SD=125.5) minutes of mean daily sitting time at T0 and 696.7 (SD=117.2) minutes at T1, t(38)=−1.34, p=.19). The mean within-person difference was small (Cohen's d=−0.21, Δ=−15.4 minutes, 95% CI=−7.9, 38.6). Participants had 455.4 (SD=185.0) minutes of mean daily prolonged sitting time at T0 and 433.5 (181.3) minutes at T1, t(38)=−1.67, p=.11. The mean within-person difference was small (Cohen's d=−0.27, Δ=−21.8 minutes, 95% CI=−4.6, 48.3). There was also no statistical differences in the mean daily number of sit-to-stand transitions and fragmentation index between T0 and T1. After adjusting for waking time, participants had 48.3 (SD=17.4) mean daily sit-to-stand transitions at T0 and 47.5 (18.6) at T1, t(38)=−.58, *p*=.56. The mean within-person difference was negligible (Cohen's *d*=−0.08, Δ=−.8, 95% CI=−.09, .08). The mean fragmentation index was 4.2 (SD=1.8) bouts per minute at T0 and 4.3 (SD=2.0) at T1, t(38)=−0.10, *p*=.92. The mean within-person difference was negligible (Cohen's *d*=−0.11, Δ=0.0, 95% CI=−0.3, 0.3).

Associations among sedentary behavior metrics.

The fragmentation index demonstrated a stronger association with prolonged sedentary time (*r*=−0.83 and −0.87, p<.001) than total sedentary time (*r*=−0.58 and −0.60, p<.001, Table 3). Sit-to-stand transitions demonstrated a strong association with prolonged sedentary time (*r*=−0.51 and −0.67, p<.001) and was not associated with total sedentary time (*r*=−0.13 and −0.27, p=.37 and .10).

Discussion

We sought to describe the stability of sedentary behavior metrics (total sitting time, prolonged sitting time, number of sit-to-stand transitions, fragmentation index) over 6 weeks among ambulatory people with stroke. We also explored the relationships among sedentary behavior metrics. Within-group change over 6 weeks in the mean daily total sitting time and prolonged sitting time was small (*d*=−0.27 to −0.21). The confidence intervals suggested that mean sitting time seems unlikely to vary greater than 38.9 minutes per day, and that mean prolonged sitting time may be unlikely to vary by greater than 48.6 minutes per day over 6 weeks. Within-group change over 6 weeks in the mean daily number of sit-to-stand transitions and the fragmentation index was also stable with negligible differences (*d*=−0.11 to −0.02). Exploratory analyses suggested that prolonged sitting was more strongly associated with the fragmentation index than with the number of sit-to-stand transitions. These findings facilitate interpretation of within-group change over time in post-stroke sedentary behavior intervention research. They also highlight the need to clearly define sedentary behavior metrics and further explicate patterns of post-stroke sedentary behavior.

We identified stability in sedentary behavior metrics over 6 weeks. While consistent with prior studies of post-stroke sedentary behavior, these results contrast with evidence of daily variability in physical activity among older adults [17–21,26,27,39–41]. Survivors of stroke have residual stroke-related impairments and functional limitations that may limit physical activity. Activities that require standing or walking may be affected by motor impairments. Planning and executing physical activities may be affected by cognitive impairments. Motivation to engage in physical activities may be affected by post-stroke depressive symptoms, pain, or fatigue. Stability in high levels of sedentary behavior may be related to stability of these residual impairments and availability (or lack thereof) of social supports for physical activity [42,43]. An alternative explanation may be that collapsing 7-day activity monitoring data into a single daily mean masks within-person variability. Future studies that describe daily variability in sedentary behavior may be informative for future intervention development.

The present study fills a gap in reporting among descriptive and intervention studies of post-stroke sedentary behavior. Descriptive longitudinal studies among survivors of stroke report sedentary behavior patterns using the fragmentation index and number of sit-to-stand transitions [21,26,27]. Intervention studies report sedentary behavior as either total time spent in sitting or sitting time accumulated in prolonged bouts [13,17,28]. These studies have reported post-intervention reductions in prolonged sitting time accumulated in bouts of 30 minutes or more that range from 36.1 +/−65.0 to 54.9 +/−81.1 minutes per day [13,28]. The magnitude of these changes relative to natural variability in prolonged sitting among survivors of stroke was unclear. To our knowledge, this is the first study that reports descriptively on patterns of *prolonged sitting* accumulated in bouts of greater than or equal to 30 minutes in survivors of stroke. Breaking up sitting time into short bouts (thereby reducing prolonged sitting) is associated with improved cardiometabolic control among people with impaired cardiovascular function [11]. Sedentary behavior research has not yet determined a dose-response relationship defining "prolonged" sitting, nor was a threshold identified which defines "too much" sitting [44]. Thus, measuring the effects of interventions that aim to *break up* or fragment sedentary behavior remains challenging.

Challenges conceptualizing and measuring sedentary behavior have confronted the field since its inception [16,45]. The application of multiple measurement approaches in stroke limits comparison of sedentary behavior findings across studies. We identified a strong association between prolonged sitting and the fragmentation index that was replicated over two time points. While this suggests that these metrics may assess similar constructs, we are mindful of conceptual implications of each metric. Measuring the total amount of time in bouts of a specified duration (e.g., 30 minutes or more) requires the researcher to select a cut-point which defines *prolonged* sitting. Clear evidence for specific cut-point defining prolonged sitting has not been established [44]. The fragmentation index eliminates the researcher's need to select a cut-point [23]. However, the fragmentation index does not account for varied distribution of sit-to-stand transitions throughout the day. For example, among two people who have equal fragmentation indices, one may have a high concentration of sit-to-stand transitions in the morning and accumulate a substantial amount of prolonged sitting in the afternoon. The other may have an even distribution of sit-to-stand transitions throughout the day, thus accumulating less prolonged sitting time.

This study carries several limitations. The sample size was small, but consistent with prior studies examining post-stroke sedentary behavior [26,27]. Although this limited the ability to detect statistically significant within-group changes, the 95% confidence intervals are informative. The small sample size also limited our ability to examine covariates of variability. In addition, half of the sample was recruited for an intervention study under restricted inclusion criteria. Baseline descriptors aligned with study criteria were similar between samples, permitting the sample to be pooled. However, clinical characteristics, concurrent engagement in rehabilitation programs (occupational, physical, or speech therapy), and sedentary behavior patterns of people seeking intervention may differ from those who enrolled in a descriptive study. Studies inclusive of broader samples not associated with an intervention study may confirm these findings and further explain sedentary behavior patterns relative to motivators for behavior change (perceived need, intention, readiness). Broader samples should include survivors of stroke who are less mobile and who may benefit from different approaches for reducing post-stroke sedentary behavior. Finally, the analyses of correlations among sedentary behavior metrics should be interpreted cautiously, as these metrics are not mutually exclusive. Although these metrics overlap and contain each other, correlational analyses point to metrics that may provide distinct information about sedentary behavior patterns. Furthermore, these findings may guide interpretation of findings across sedentary behavior studies that use different metrics to report their findings.

This work supports the future development of sedentary behavior interventions. Sedentary behavior metrics remained stable over time periods associated with existing sedentary behavior and physical activity interventions. As such, measurements of sedentary behavior using these metrics can be used to demonstrate the impact of interventions. Future exploration of sedentary behavior patterns that elucidate day-to-day variability that may also support planning for interventions that reduce post-stroke sedentary behavior to optimize health.

Conclusion

Survivors of stroke experience a high level of sedentary behavior that appears to be stable over 6 weeks. Further exploration of daily and hourly patterns that drive these behaviors will guide toward precise intervention approaches that are effective for promoting active lifestyles among survivors of stroke.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Table 1.

Participant characteristics

Mean (SD) or %(n)	Pooled sample n=39	Intervention n=19	Descriptive n=20	*p*-value
Age (years)	66.3 (13.2)	70.8 (11.5)	62.0 (13.6)	.037*
Gender, *female*	41 (16)	58 (11)	25 (5)	.037*
Race				.579
White	87 (34)	84 (16)	90 (18)	
Black	10 (4)	11 (2)	10 (2)	
Other	3 (1)	5 (1)	0 (0)	
Stroke chronicity (months)	40.4 (37.4)	27.9 (14.1)	52.9 (48.4)	.042*
Stroke type, *ischemic*	82 (32)	90 (17)	75 (15)	.239
Motor function (SIS-PHYS)	58.7 (21.2)	62.2 (21.1)	55.3 (21.3)	.322
Cognitive function (NIH)	47.6 (9.8)	51.1 (7.7)	44.7 (10.7)	.053
Depressive symptoms (PHQ-9)	4.0 (4.1)	3.8 (3.4)	4.3 (4.7)	.729
Mobility (SIS-MOB)	78.9 (16.1)	78.8 (17.5)	78.9 (15.7)	.978
ADL Difficulty (SIS-ADL/IADL)	82.7 (16.4)	81.2 (18.0)	84.1 (14.3)	.579
T0 Total Sitting Minutes	704.8 (125.9)	719.6 (116.3)	690.8 (135.9)	.483
T0 Prolonged Sitting Minutes	450.3 (184.5)	471.8 (171.8)	429.9 (198.1)	.485
T0 Count Sit-to-Stand Transitions	47.9 (17.1)	46.2 (19.4)	49.6 (14.8)	.545
T0 Fragmentation Index	4.4 (1.8)	4.1 (1.8)	4.6 (1.8)	.321

* Between-sample difference at $p<.05$

Table 2.

Mean daily outcomes on sedentary behavior metrics

	Unadjusted					Adjusted for Waking Time				
	T0	**T1**	**Difference**	***d***	***p*-value**	**T0**	**T1**	**Difference**	***d***	***p*-value**
Total sitting (total minutes)	704.8 (125.9)	690.3 (116.6)	−14.5 (71.1)	−.20	.21	712.1 (125.5)	696.7 (117.2)	−15.4 (71.8)	−.21	.19
Prolonged sitting (total minutes in ≥30 minute bouts)	450.3 (184.5)	430.1 (179.3)	−20.2 (80.6)	−.25	.12	455.4 (185.0)	433.5 (181.3)	−21.8 (81.5)	−.27	.10
Sit-to-stand transitions (total number)	47.9 (17.1)	47.0 (18.3)	−0.9 (8.6)	−.02	.53	48.3 (17.4)	47.5 (18.6)	−.8 (8.8)	−.08	.56
Fragmentation index* (transitions per hour)	4.4 (1.8)	4.3 (2.0)	0.0 (1.0)	−.11	.92	-	-	-	-	-
Waking time (total minutes)	953.9 (84.2)	932.3 (86.5)	−21.6 (60.4)	−.31	.03	-	-	-	-	-

Note. Outcomes are averages based on 4 to 7 days of activity monitoring. Data reported are Mean (SD).

*Computed as number of sit-to-stand transitions/total sitting hours

Table 3.

Correlations (*r*) among sedentary behavior metrics

	Prolonged sitting		Sit-to-stand breaks		Fragmentation index	
	T0	**T1**	**T0**	**T1**	**T0**	**T1**
Total sitting	.86**	.82**	−.13	−.27	−.59**	−.60**
Prolonged sitting	-	-	−.51**	−.67**	−.83**	−.87**
Sit-to-stand breaks	-	-	-	-	.84**	.90**

** p<.01;

Note: Unadjusted total sitting time and unadjusted prolonged sitting used in correlations.