

Quantification of everyday motor function in a geriatric population

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Abstract—This pilot study evaluated variability in physical activities and the correlations between walking, two types of postural transitions, and falls efficacy with an ambulatory activity monitor. An 11-subject convenience sample wore the monitor for 2 consecutive days; in addition, 7 subjects carried the monitor on 1 day of the following week. Demographic characteristics of the sample were age: mean \pm standard deviation [SD] = 87.8 \pm 2.5 yr, body mass index: mean \pm SD = 25.3 \pm 2.1 kg/m², and Mini-Mental State Examination score: mean \pm SD = 27.5 \pm 2.0. Analyzed movements were sit-to-stand (SiSt) and stand-to-sit postural transitions, dynamic activity (walking), and static behavior (sitting, standing, lying). Significant correlations were found for the SiSt transition duration (TD) between days (intraclass correlation coefficient = 0.78). No differences were found between the durations of sitting ($p = 0.8$), lying ($p = 0.72$), standing ($p = 0.06$), and walking ($p = 0.6$). These parameters showed highly variable correlation coefficients. A significant correlation was observed between falls efficacy and SiSt measures ($r = 0.84$, $p < 0.01$, $df = 9$). We reliably determined the SiSt TD after subjects wore the monitor for 1 day in the home environment. Poor correlations between 2 consecutive measurement days for dynamic and static activity underline the necessity of recording further days to assess physical activity levels in the geriatric population.

Key words: activity of daily living monitoring, ambulatory activity monitor, correlations, falls efficacy, mobility disability, physical activity assessment, postural transitions, rehabilitation, sit-to-stand, stand-to-sit.

INTRODUCTION

Successful aging is a worldwide aim. Demographic changes challenge policy makers to put increasing effort into dealing with an aging population [1]. Many older adults have a walking disability that causes loss of independence and social isolation and thus greatly reduces their quality of life [2–4]. Persons with a walking disability have an increased risk of repeated falls [5] and a reduced survival compared with peers with nondisabled walking [6–7]. In light of these negative consequences, much research has focused on the determinants of walking disability. Recognition of such determinants could assist both clinicians and policy makers in developing intervention strategies aimed at prevention.

Mobility disability in older adults, defined by individuals' ability to move about effectively in their surroundings,

Abbreviations: CV = coefficient of variation, FES = Falls Efficacy Scale, ICC = intraclass correlation coefficient, SD = standard deviation, SiSt = sit-to-stand, StSi = stand-to-sit, TD = transition duration.

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predicts the onset of disability in tasks essential to living independently in the community and caring for themselves [8]. In community-dwelling older adults, mobility is a strong predictor of physical disability and is often the first area in which older adults become disabled [8–11]. Furthermore, one of several environmental dimensions that differ between subjects that are nondisabled and those that are disabled is postural transition [12]. For postural transitions, the sit-to-stand (SiSt) strategy is described as a good candidate for revealing functional limitations of the neuromusculoskeletal system [13], whereas the stand-to-sit (StSi) strategy is considered a possible early marker of functional limitation in postural control [14]. Besides the fact that activities such as the SiSt transfer and walking are important for functional independence, the amount of time spent in activity each day also provides important information on functional status [15]. Therefore, an understanding of the quantity (or lack) of physical activity and the quality of postural transitions seems particularly important in addressing the rehabilitation needs of older individuals, and measuring mobility-related activities during regular daily life of older adults seems desirable.

Monitoring of human movement with an ambulatory activity monitor allows for longitudinal tracking of important movement parameters and could potentially monitor subjects for adverse events, such as falls, during unsupervised living. Moreover, movement measurements made in the clinic may not accurately reflect functional ability in a home environment [16]. New activity monitoring methods that objectively measure aspects of mobility not measured by other instruments (i.e., what a person really “does” during daily life outside a laboratory setting) should be evaluated [17]. This pilot study evaluated variability in daily physical activity in a sample of older adults.

This study used a validated ambulatory activity monitor and aimed to (1) provide insight into motor function in older adults living in a residential care facility through acquisition of several basic components of everyday physical activity and (2) acquire insight into the performance of two types of postural transitions (i.e., SiSt and StSi) through long-term monitoring in a geriatric population. For this purpose, the day-to-day and week-to-week measures of both physical activity and postural transitions were compared [18].

METHODS

Subjects

This study received prior ethical approval from the Eidgenössische Technische Hochschule Zürich Research Ethics Committee. All participants signed an informed consent document prior to initiation of the study. A convenience sample of 11 older adults was recruited from a residential care facility in the Swiss town of Zürich. Inclusion criteria were residential status, age over 70, signed informed consent statement, and the ability to walk 6 m. Subjects were excluded if they had severe cognitive impairment (Mini-Mental State Examination), rapidly progressive or terminal illness, acute illness or unstable chronic illness, myocardial infarction, or insulin-dependent diabetes mellitus.

Activity Monitor

All subjects carried an ambulatory activity monitor that included a kinematic sensor attached to the chest and a small, lightweight (300 g, 130 mm × 70 mm × 30 mm) portable data logger (Physilog[®], BioAGM, La Tour-de-Peilz, Switzerland) carried on the waist. The kinematic sensor was composed of a miniature piezoelectric gyroscope (Murata Manufacturing Company, Ltd, Kyoto, Japan; model ENC-03J, ±400°/s) that measured sagittal plane trunk angular velocity (g_s) and a biaxial miniature accelerometer (Analog Devices, Inc, Norwood, Massachusetts; model ADXL202, ±2 g), which measured vertical ($a_{v,s}$) and frontal trunk accelerations (a_{fs}) (**Figure 1**). The gyroscope and the accelerometer along with their conditioning electronics were packaged in a very small, lightweight box (25 g, 25 mm × 25 mm × 15 mm) and directly attached with medical patches fixed on the skin in front of the sternum. These battery-operated sensors have low energy consumption and are appropriate for ambulatory monitoring [18–19].

The signals from the gyroscope and accelerometer were amplified and low-pass filtered (cutoff frequency = 17 Hz) to remove electronic noise. Signals were then digitized at a 40 Hz sampling rate and recorded by the data logger. At the end of the recording, the data were transferred to a computer for analysis of postural transitions. To discriminate between sitting and standing postures, we first determined the postural transition between these two positions using information extracted from the gyroscope (**Figure 2(a)**). In general, during these postural transitions (SiSt and StSi), the subject first leans the trunk

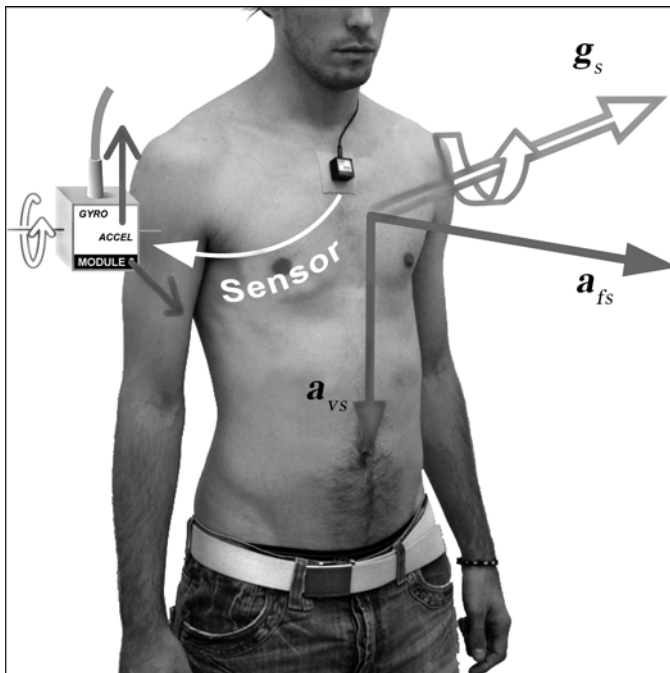


Figure 1.

Kinematic sensor composed of one miniature piezoelectric gyroscope (Gyro) (Murata Manufacturing Company, Ltd, Kyoto, Japan; model ENC-03J, $\pm 400^\circ/\text{s}$) that measured sagittal plane trunk angular velocity (g_s) and biaxial miniature accelerometer (Accel) (Analog Devices, Inc, Norwood, Massachusetts; model ADXL202, ± 2 g), which measured vertical (a_{vs}) and frontal trunk accelerations (a_{fs}).

forward and then leans the trunk backward (**Figure 2(b)**). This pattern can be identified by integration of the gyroscope signal and suitable signal processing [18,20]. The transition duration (TD) for postural transitions was defined as the time interval from beginning of tilt down until the end of tilt back during a SiSt (vs StSi) transition (**Figure 2(b)**). This TD includes not only the rising time but also the prephase of rising, when a subject leans forward for rising, as well as the postphase of rising, when a subject leans back to his or her initial posture.

Finally, the detected postural transition was classified into SiSt or StSi by pattern recognition of vertical acceleration (a_v) during the postural transition interval. Indeed, by second derivation of vertical displacement (Dv) during a postural transition interval, we can observe acceleration patterns similar to **Figure 2(c)** and **(d)** for SiSt and StSi, respectively [19]. We used a postprocessing algorithm to identify and remove falsely detected SiSts or StSis based on some simple rules, e.g., walking

while sitting was impossible, two successive SiSt or StSi transitions were impossible, and leaning backward and long periods of continuous rest during a standing position were considered unlikely. The list of all rules and their rationale was detailed previously [18–19]. In addition, we used an algorithm to estimate undetected SiSts or StSis according to the previous and/or subsequent activities (i.e., pre- or postpostural transition, lying, and walking). For example, if a lying state was detected immediately after a standing position with no sitting in between, the algorithm added a StSi transition just before lying. However, for such an added postural transition, the duration remained unknown.

We identified walking by analyzing the vertical accelerometer every 5 s. We then used wavelet decomposition to enhance the walking pattern and to reduce noise and drift from other activities, such as postural transitions and turning. A walking period was defined as an interval with at least 3 successive step cycles. Furthermore, various algorithms allowed the physical activity to be categorized as lying, sitting, standing, and walking [18–19].

For the SiSt and StSi transitions, both the total number of transitions performed and the TD were recorded. For the physical activities (walking, lying, standing, sitting), the time of performance within the measurement period was recorded. The system was validated with a camera-based system (Vicon, Oxford, England) for short-term monitoring and an observer for long-term monitoring. Sensitivity and specificity were 93 and 82 percent for identifying SiSt transition and 82 and 94 percent for StSi transition, respectively. Regarding the duration of activity and postures, sensitivities and specificities were, respectively, 90.2 and 93.4 percent for sitting, 92.2 and 92.1 percent for standing and walking, and finally, 98.4 and 99.7 percent for lying [19]. A more detailed description of the instrument can be found elsewhere [18–21].

Protocol

To obtain information on the between-day variance in physical activity and possible differences in between-day variance on similar weekdays and different weekdays, we monitored the subjects during 2 consecutive weekdays (two 11-hour measurements) and during 1 of these days of the subsequent week (one 11-hour measurement). We performed measurements during 2 consecutive weekdays for all subjects of the sample ($n = 11$). For 7 subjects, we collected data on 1 of the subsequent

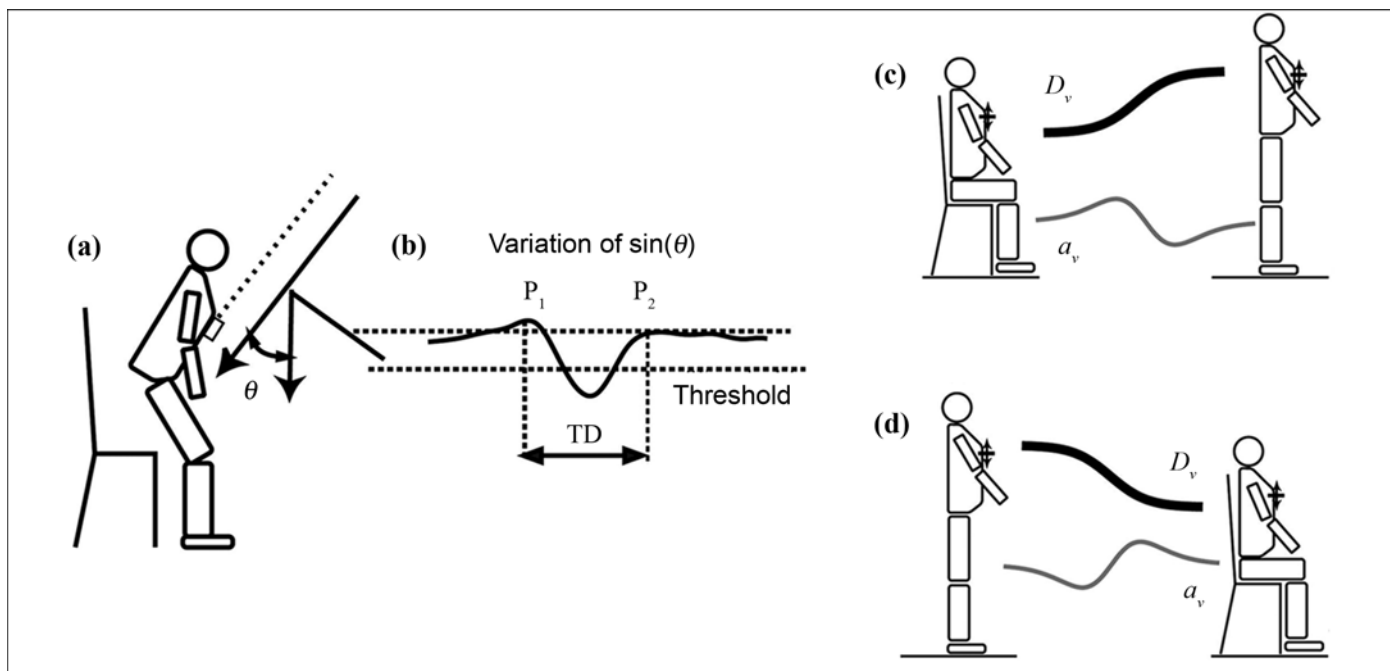


Figure 2.

During sit-to-stand (SiSt) or stand-to-sit (StSi) postural transitions, trunk first (a) leans forward and then leans backward. Detected postural transitions were classified SiSt or StSi by pattern recognition of vertical acceleration (a_v) during (b) postural transition duration (TD) (time interval between P_1 and P_2). By second derivation of vertical displacement (D_v) during TD, we identified acceleration patterns of postural transitions (c) SiSt and (d) StSi.

weekdays. For these 7 subjects, the week-to-week analyses were performed on data from 1 of the first 2 consecutive 11-hour measurement periods (week 1) and a subsequent 11-hour measurement period 1 week later (week 2). All measurements were performed in the same 6-week period.

To interfere as little as possible with normal daily activity patterns, we fitted the subjects in their private rooms with the activity monitor between 8:00 and 9:30 am. If necessary, we visited the subjects during the measurement period to replace the batteries or memory card or consolidate the attachment of the sensors. During the activity monitoring, subjects were not allowed to swim or take a shower. After the measurement, we visited the subjects again to remove the instrumentation and to ask questions about the kinds of activities performed, the convenience of the activity monitor, and possible abnormalities (such as illness) during the measurements.

To avoid measurement bias, we did not initially explain the real aim of the study to the subjects [22]. They were told that the measurements would be used to obtain insight into the practical problems subjects may experience during long-term measurement with the

activity monitor. Furthermore, subjects were instructed to continue their ordinary daily life. After the measurements, complete information on the aim of the study was given and also the reason for not giving the information before the measurements. Only the information of subjects who afterwards agreed with this procedure was included in the final data analysis.

Questionnaire Assessment

In our sample, we used the Falls Efficacy Scale (FES), a 10-item rating scale, to assess subjects confidence in performing daily activities without falling. Each item is rated from 1 = extreme confidence to 10 = no confidence at all. Participants who reported avoiding activities because of fear of falling had higher FES scores, representing lower self-efficacy or confidence, than those not reporting fear of falling. This scale is correlated with measures of balance and gait and predicts decline in functional capacity [23].

Data Analysis

In the analysis, only corresponding measurement periods between days or between subjects were used;

e.g., in case subject data were missing between 10:00 am and 12:00 pm on day 1, data from this period on the other measurement days were excluded from the analysis.

For the day-to-day comparisons, the first 11 hours of the 22-hour measurement period were identified as day 1 and the second 11 hours were identified as day 2. For the week-to-week comparison, some subjects' day 1 data was assigned as week 1 and others' day 2 data was assigned as week 1, depending on which weekday was measured in the second week. Between-day variance of similar and different weekdays was based on measurements with 1 week in between. We calculated intraclass correlation coefficients (ICCs) for the number of transitions and the mean TD for the SiSt and StSi transitions to analyze the test-retest reliability of these parameters.

A Wilcoxon signed rank test was performed for differences in duration of static activities (expressed as percent of the measurement period), duration of dynamic activities (expressed as percent of the measurement period), mutual distribution of activities within the static activity category, and number of walking periods (a walking period was defined as an interval of at least 3 successive step cycles). Pearson product moment correlation coefficients were calculated for the degree of association between day-to-day and week-to-week measures of these variables.

To measure the day-to-day and week-to-week variability between physical activities, we calculated the coefficient of variation (CV) as the ratio of the standard deviation (SD) to the mean, expressed as a percentage ($CV = SD/mean \times 100$) [24] for both the group postural transitions and the physical activity indexes. To gain information on the individual stability of postural transitional behavior, we calculated individual CVs for the two postural transitions.

We calculated Pearson product moment correlation coefficients between the FES scores and the mean number of SiSt and StSi transitions over 2 consecutive days, the FES scores and the mean TD for SiSt and StSi transitions over 2 consecutive days, and the FES scores and walking time to analyze the strength of the relationships. We used Statistical Package for the Social Sciences (SPSS Inc, Chicago, Illinois) for all statistics; statistical significance was assumed at $p < 0.05$.

RESULTS

We tested six female and five male subjects who lived in a residential care facility (age: mean \pm SD = 87.8 ± 2.5 yr, range 84–92 yr; body mass index: mean \pm SD = 25.3 ± 2.1 kg/m², range 20.5–29.1 kg/m²; Mini-Mental State Examination score: mean \pm SD = 27.5 ± 2.0 , range 24–30; and FES score: mean \pm SD = 11.9 ± 3.0 , range 10–19). Seven subjects participated regularly in a twice weekly in-house training program that emphasized muscular strength and postural balance exercises; four subjects were not participating in any form of physical training.

All subjects completed all the required phases of monitoring. The sensor was well-tolerated in the required sternum-attachment position. One subject with extensive hair on his chest did not notice the loosening of the sensor during 1 day of monitoring. This resulted in only 2 hours of valid measures and the exclusion of the static and dynamic physical activity data for this subject. The SiSt and StSi values from the 2 hours of continuous monitoring remained in the database for analysis.

Two reports of discomfort related to the waist bag containing the recording device for the monitor were noted. One subject complained about being uncomfortably warm underneath the bag, and one subject noted discomfort in relation to wearing the bag and visiting the toilet. However, all subjects were compliant in continuous wearing of the monitor throughout the monitoring period.

Figure 3 shows the physical activity extracted by the system for a typical subject during day 1 of week 1.

Reliability of Static and Dynamic Physical Activity Indexes

Table 1 lists mean, SD, and CV values for the static and dynamic activities expressed as percent of the measurement period for dynamic (walking) and static activities (sitting, standing, and lying).

We performed a Wilcoxon signed rank test on the day-to-day duration of static activities (expressed as percent of the measurement period) for sitting ($z = -0.255$, $n = 10$), standing ($z = -1.886$, $n = 10$), and lying ($z = -0.357$, $n = 10$); the results were found to be nonsignificant (p sitting = 0.80, p standing = 0.06, p lying = 0.72) for a two-tailed test. These results suggest that the duration of static activities on different days of the same week was not different in our sample. Similar results were found for the week-to-week comparisons.

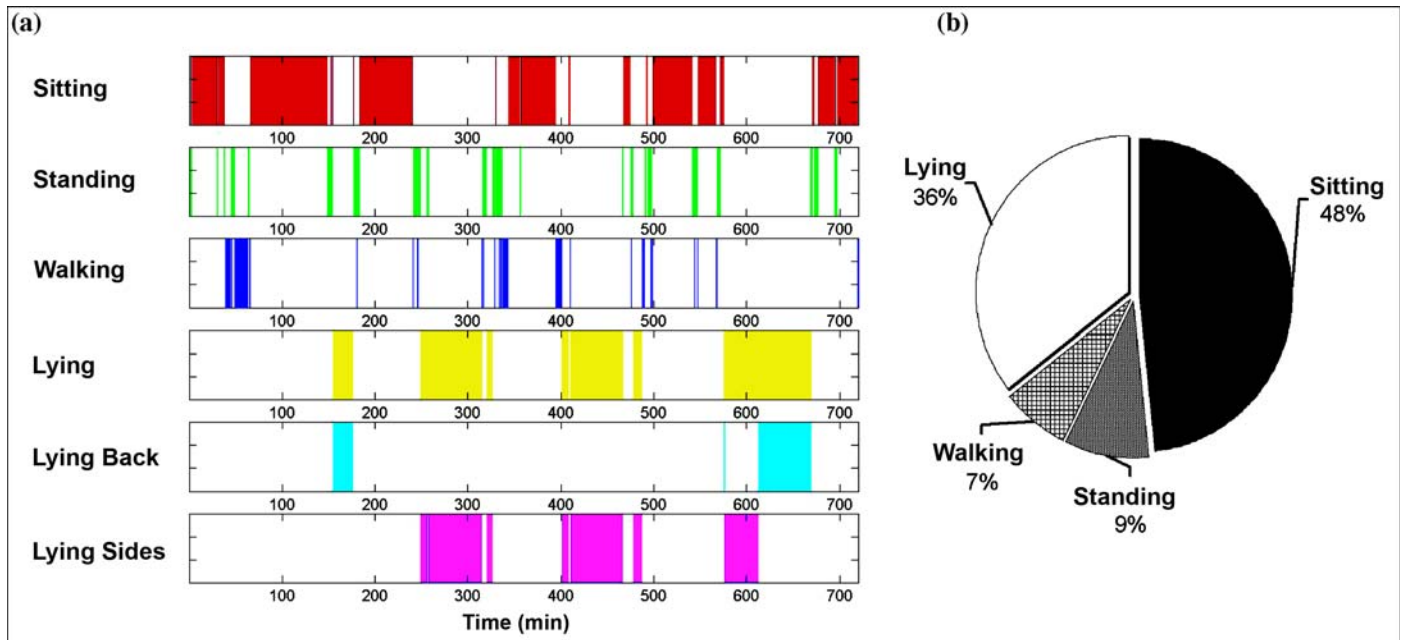


Figure 3.

Physical activity measured by ambulatory activity monitor for typical subject on day 1, week 1, presented as (a) time (min) of performance within measurement period and (b) percent of measurement period.

Table 1.

Reliability of static and dynamic physical activities for day-to-day ($n = 10$) and week-to-week ($n = 7$) comparisons. Physical activity data expressed as percent of measurement period (11 hours of continuous measurement).

Physical Activity	Mean \pm SD	Range	CV (%)	r
Sitting				
Day 1	57.6 \pm 15.1	34–79	26.2	0.07
Day 2	54.6 \pm 10.5	36–64	19.3	
Week 1	48.7 \pm 8.3	34–61	17.1	0.93*
Week 2	51.9 \pm 10.3	38–64	19.8	
Standing				
Day 1	18.6 \pm 6.9	8–31	37.4	0.27
Day 2	23.6 \pm 5.7	17–36	24.2	
Week 1	23.9 \pm 7.0	12–36	29.4	0.48
Week 2	23.0 \pm 6.7	17–36	29.1	
Lying				
Day 1	15.6 \pm 14.6	0.2–38	93.7	0.41
Day 2	14.3 \pm 11.9	0.1–38	83.1	
Week 1	19.5 \pm 10.6	10–38	54.0	0.80†
Week 2	16.4 \pm 10.6	0.1–33	64.5	
Walking				
Day 1	8.2 \pm 3.3	3–13	40.6	0.40
Day 2	7.6 \pm 4.0	3–17	52.8	
Week 1	7.9 \pm 1.6	5–10	19.7	0.22
Week 2	8.7 \pm 3.8	6–17	43.2	

* $p < 0.01$.

† $p < 0.05$.

CV = coefficient of variation, r = Pearson product moment correlation coefficient, SD = standard deviation.

The Pearson product moment correlation coefficients that were calculated for determining the degree of association between these measures revealed nonsignificant association for day-to-day ($r = 0.07$, $n = 10$) and significant association for week-to-week ($r = 0.93$, $p < 0.01$, $n = 7$) sitting. These results indicate that no correlation exists between sitting duration on consecutive weekdays; however, on similar days in different weeks such a correlation exists.

Neither day-to-day ($r = 0.27$, $n = 10$) nor week-to-week standing ($r = 0.48$, $n = 7$) showed significant associations. These results reveal that no correlation exists between standing on consecutive weekdays or on similar days in different weeks.

Day-to-day ($r = 0.41$, $n = 10$) lying showed no significant association; whereas, week-to-week lying ($r = 0.80$, $p < 0.05$, $n = 7$) showed significant association. These results imply that no correlation exists between lying duration on consecutive weekdays; whereas, on similar days in different weeks, such an association exists.

We performed a Wilcoxon signed rank test on the duration of walking ($z = -0.534$, $n = 10$) (expressed as percent of the measurement period) and the results were found to be nonsignificant ($p = 0.60$), which suggests similar amounts of walking duration on different days of the same week. Similar results ($z = -0.105$, $p = 0.92$, $n = 7$) were found for the week-to-week comparison. The Pearson product moment correlation coefficients that were calculated for determining the degree of association between this measure revealed nonsignificant association for day-to-day ($r = 0.4$, $df = 8$) and week-to-week ($r = 0.22$, $df = 5$) walking. These results indicate that no correlation exists between walking on consecutive weekdays or on similar days in different weeks.

We performed a Wilcoxon signed rank test on the number of walking periods (a walking period is defined as an interval with at least 3 successive step cycles) and the results were found to be nonsignificant for both the day-to-day ($p = 0.80$) and week-to-week ($p = 0.34$) measures. The Pearson product moment correlation coefficients that were calculated for determining the degree of association between this measure revealed nonsignificant association for day-to-day ($r = -0.08$, $n = 10$) and week-to-week ($r = 0.64$, $n = 7$) walking periods. Therefore, no correlation exists between walking periods on consecutive weekdays or on similar days in different weeks.

Reliability of Postural Transition Counts

Tables 2 and **3** summarize the group results for the day-to-day and week-to-week measurements of the SiSt and StSi maneuver, respectively, for which the postural TD was estimated by the algorithm. **Table 4** presents the individual CVs of the SiSt and StSi maneuver.

The day-to-day total SiSt transition count (ICC = 0.60) did not provide a reliable measure of daily activity. Day-to-day variability of this measure was rather high as reflected by the CV. The average SiSt TD (ICC = 0.78, $p < 0.05$) did provide a reliable measure of daily activity. Day-to-day variability of this measure ranged between 6.3 and 8.3 percent for the group data. **Figure 4** depicts the scatter plot of day-to-day reliability of the mean SiSt TD for older adults in a residential care facility. The week-to-week total SiSt transition count (ICC = 0.53) did not provide a reliable measure of daily activity of the group as reflected in a rather high CV. The reliability of the week-to-week mean SiSt TD resulted in an invalid ICC value because of nonsignificant between-subject variance ($n = 7$).

The day-to-day total StSi transition count (ICC = 0.77, $p < 0.01$) did provide a reliable measure of daily activity for the observed group. Day-to-day variability of this measure was rather high as reflected by the CV. The mean StSi TD (ICC = 0.55) did not provide a reliable measure of daily activity. Day-to-day variability of this measure ranged between 6.2 and 11.1 percent. The week-to-week total StSi transition count (ICC = 0.35) did not provide a reliable measure of daily activity as reflected in a rather high CV. The reliability of the week-to-week mean StSi TD resulted in an ICC value of 0.37 ($n = 7$).

The CVs of the TD for both the StSi and SiSt movements are shown in **Table 4**. This table shows that individual subject performance exhibited high variability.

Correlation with Falls Efficacy Scale

In our sample, a positive, significant correlation was found between FES scores and the mean SiSt TD ($r = 0.84$, $p < 0.01$, $df = 9$) from the 2 consecutive monitoring days ($n = 11$). This result indicates that a positive correlation exists among older adults in a residential care facility between falls efficacy and the SiSt TD (the more confident one is in performing daily activities without falling, the less time is needed to perform the transition).

A negative, nonsignificant correlation was found between FES score and the mean StSi TD ($r = -0.36$, $df = 9$) calculated from the 2 consecutive monitoring days.

Table 2.

Day-to-day and week-to-week data for number of and mean time required for sit-to-stand (SiSt) transitions in older adults in residential care facility.

Subject No.	Day 1		Day 2		Week 1		Week 2	
	No.	Time (s)	No.	Time (s)	No.	Time (s)	No.	Time (s)
1	52	5.0	42	4.9	—	—	—	—
2	21	4.8	35	4.9	—	—	—	—
3	55	5.6	3	5.5	—	—	—	—
4	47	4.8	43	4.2	—	—	—	—
5	31	4.7	47	4.6	31*	4.7*	71	4.9
6	42	4.3	52	4.8	52	4.8	40	4.5
7	33	5.2	68	4.9	68	4.9	54	4.7
8	86	4.3	69	4.6	86*	4.3*	74	4.9
9	87	4.6	73	4.7	73	4.7	73	4.7
10	53	4.8	44	4.6	44	4.6	80	4.6
11	35	4.3	36	4.7	35*	4.3*	31	5.0
Mean ± SD	49.3 ± 21.2	4.8 ± 0.4	46.6 ± 19.7	4.8 ± 0.3	60.1 ± 22.6	4.7 ± 0.2	55.7 ± 16.7	4.7 ± 0.2
CV (%)	43.0	8.3	42.3	6.3	37.6	4.3	30.0	4.3
ICC	—	—	0.60	0.78 [†]	—	—	0.53	Invalid [‡]

*Data from measurement day 1. All other week 1 data from measurement day 2.

[†] $p < 0.01$.[‡]Negative, invalid ICC obtained for week-to-week reliability because of nonsignificant between-subject variance ($n = 7$).

CV = coefficient of variation, ICC = intraclass correlation coefficient, SD = standard deviation.

Table 3.

Day-to-day and week-to-week data for number of and mean time required for stand-to-sit (StSi) transitions in older adults in residential care facility.

Subject No.	Day 1		Day 2		Week 1		Week 2	
	No.	Time (s)	No.	Time (s)	No.	Time (s)	No.	Time (s)
1	38	5.2	43	5.3	—	—	—	—
2	16	5.0	34	4.8	—	—	—	—
3	36	4.6	4	3.3	—	—	—	—
4	46	4.7	35	4.3	—	—	—	—
5	28	4.4	43	4.7	28*	4.4*	65	4.7
6	34	4.7	48	4.6	48	4.6	36	5.1
7	32	4.9	59	4.9	59	4.9	46	4.4
8	84	4.1	66	4.6	84*	4.1*	54	4.4
9	84	4.7	70	4.8	70	4.8	70	4.8
10	50	4.4	42	4.6	42	4.6	76	4.6
11	34	4.4	32	4.2	34*	4.4*	27	4.8
Mean ± SD	44.3 ± 21.1	4.6 ± 0.3	44.3 ± 21.1	4.6 ± 0.5	56 ± 22.7	4.6 ± 0.3	49.6 ± 14	4.6 ± 0.3
CV (%)	49.6	6.2	42.0	11.1	40.5	5.9	28.2	5.3
ICC	—	—	0.77 [†]	0.55	—	—	0.35	0.37

*Data from measurement day 1. All other week 1 data from measurement day 2.

[†] $p < 0.01$.

CV = coefficient of variation, ICC = intraclass correlation coefficient, SD = standard deviation.

This result reveals that no correlation exists among older adults in a residential care facility between falls efficacy and StSi TD.

A negative, nonsignificant correlation was found between FES score and walking time (expressed as percent of the measurement period) on both day 1 ($r = -0.09$, $df = 9$) and day 2 ($r = -0.33$, $df = 9$).

DISCUSSION

This study aimed to (1) provide insight into motor function in older adults in a residential care facility through acquisition of data on several basic components of everyday physical activity and (2) acquire insight into the performance of two postural transitions through long-term

Table 4.

Intraindividual day-to-day and week-to-week variability in stand-to-sit (StSi) and sit-to-stand (SiSt) transitions. Data presented as mean, standard deviation (SD), and coefficient of variation (CV) for mean time (s) required for transitions performed.

Subject No.	Day 1		Day 2		Week 1		Week 2	
	Mean \pm SD	CV (%)	Mean \pm SD	CV (%)	Mean \pm SD	CV (%)	Mean \pm SD	CV (%)
1								
StSi	5.2 \pm 1.4	28.0	5.3 \pm 1.6	30.8	—	—	—	—
SiSt	5.0 \pm 1.5	29.6	4.8 \pm 1.6	32.6	—	—	—	—
2								
StSi	5.0 \pm 1.3	26.3	4.8 \pm 1.4	27.9	—	—	—	—
SiSt	4.8 \pm 1.6	33.1	4.9 \pm 1.3	25.5	—	—	—	—
3								
StSi	4.7 \pm 1.7	35.9	3.3 \pm 1.2	35.0	—	—	—	—
SiSt	5.6 \pm 1.6	27.6	5.5 \pm 2.9	52.3	—	—	—	—
4								
StSi	4.7 \pm 1.2	26.6	4.3 \pm 1.2	27.9	—	—	—	—
SiSt	4.8 \pm 1.3	27.5	4.2 \pm 1.4	32.5	—	—	—	—
5								
StSi	4.4 \pm 1.2	28.1	4.7 \pm 1.2	25.3	4.4 \pm 1.2*	28.1*	4.7 \pm 1.4	29.1
SiSt	4.7 \pm 1.6	33.9	4.6 \pm 1.5	32.5	4.7 \pm 1.6*	33.9*	4.9 \pm 1.4	28.5
6								
StSi	5.1 \pm 1.3	25.1	4.6 \pm 1.6	34.8	4.6 \pm 1.6	34.8	4.7 \pm 1.7	35.2
SiSt	4.5 \pm 1.4	29.9	4.8 \pm 1.4	29.8	4.8 \pm 1.4	29.8	4.3 \pm 1.5	34.1
7								
StSi	4.8 \pm 1.4	28.4	4.9 \pm 1.5	30.7	4.9 \pm 1.5	30.7	4.4 \pm 1.4	32.0
SiSt	5.2 \pm 1.4	27.4	4.9 \pm 1.4	28.8	4.9 \pm 1.4	28.8	4.8 \pm 1.6	33.5
8								
StSi	4.1 \pm 1.3	31.1	4.6 \pm 1.4	31.8	4.1 \pm 1.3*	31.1*	4.4 \pm 1.3	29.7
SiSt	4.3 \pm 1.5	33.9	4.6 \pm 1.6	34.9	4.3 \pm 1.5*	33.9*	4.9 \pm 1.7	34.9
9								
StSi	4.7 \pm 1.4	30.6	4.8 \pm 1.4	29.4	4.8 \pm 1.4	29.4	4.8 \pm 1.4	29.4
SiSt	4.6 \pm 1.5	32.7	4.7 \pm 1.6	33.0	4.7 \pm 1.6	33.0	4.7 \pm 1.6	33.0
10								
StSi	4.4 \pm 1.4	31.8	4.6 \pm 1.3	29.5	4.6 \pm 1.6	33.5	4.6 \pm 1.3	29.5
SiSt	4.8 \pm 1.2	25.5	4.6 \pm 1.4	30.6	4.6 \pm 1.5	32.8	4.6 \pm 1.4	30.6
11								
StSi	4.4 \pm 1.3	30.0	4.2 \pm 1.5	36.0	4.4 \pm 1.3*	30.0*	4.8 \pm 1.5	31.4
SiSt	4.3 \pm 1.6	36.2	4.7 \pm 1.3	27.3	4.3 \pm 1.6*	36.2*	5.0 \pm 1.4	28.6

*Data from measurement day 1. All other week 1 data from measurement day 2.

monitoring in a geriatric population. To fulfill these aims, we used a device that has been tested in different studies before and achieved good results in testing validity, sensitivity, and reliability [19–20].

The results of our study show that measuring the SiSt TD over 2 days in geriatric subjects unobtrusively and reliably is possible. In light of the variability identified in activity measurement of single days for the whole group and the associated CVs between 6.3 and 8.3 percent, we recommend a mean of 2 days of monitoring as a reliable and valid measure of SiSt transition. The StSi transition shows a larger CV (6.2%–11.1%), and no reliable meas-

ures were obtained over 2 days of continuous measurement. Future research should, therefore, be performed to determine the optimal monitoring period for this variable in group studies. The total number count for both transitions had high associated CVs ranging between 42.0 and 49.6 percent and should therefore not be recommended as reliable measures of physical activity.

Najafi et al. evaluated the characteristics of SiSt and StSi postural transitions and their correlation with falls risk in a sample of older adults (79 \pm 6 yr) [20]. They showed that the SiSt and StSi parameters correlated with falls risk in older adults. They also compared subjects

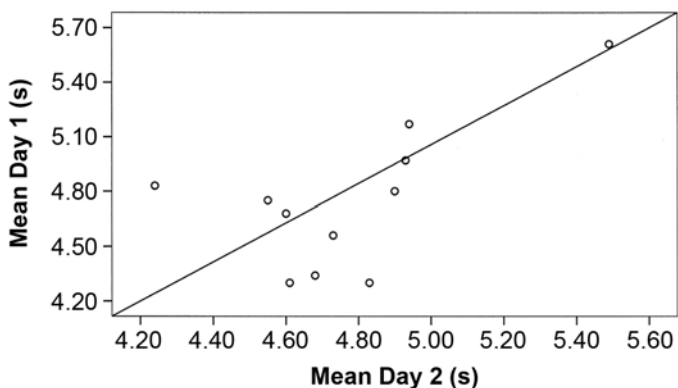


Figure 4.

Scatterplot of day-to-day reliability of mean sit-to-stand postural transition duration for older adults in residential care facility. Intraclass correlation coefficient = 0.78.

with high fall risk with those with low fall risk and found that the mean TD required for the movements discriminated between the two groups. They reported in their study that the transition type (i.e., SiSt or StSi) and the TD were not different. These results are at variance with reports from Mourey et al. who, with different methodology, reported that the SiSt TD was greater than the StSi TD for both younger (22.8 ± 1.5 yr) and older (73.2 ± 5.5 yr) subjects [25]. Both studies, however, tested only a limited number of transitions under laboratory conditions. In these circumstances, environment and motivation for the test as well as a range of transient factors may make the test result an uncertain characterization of everyday transitions. That such influences should not be neglected was indicated by the work of Hase et al. [26]. They showed that the relationship between body and chair must inevitably influence the selection of a motor command for downward-oriented movements; subjects either selected a motor strategy that required them to throw the body backward or a strategy that required them to unlock the upright body posture [26]. Another explanation for the differing results may be the definition of the postural transitions. We defined SiSt TD as the time the trunk leaned forward until the time the trunk leaned backward. Therefore, this TD included not only the rising time but also the prephase of rising, when the subject leans forward, and the postphase of rising, when the subject leans back to his or her initial position. This is in contrast to force-plate measures of the SiSt TD, for which often only the rising time is recorded. Such an approach excludes both the prephase of rising as well as the stabilization

time after rising. At the very least, the relationship between brief tests of postural SiSt and StSi transitions and transitions performed in everyday community settings requires further exploration.

The ability to accurately monitor the amount of daily physical activity in older adults on an individual level is important because physical activity is associated with both physical and mental health [27–29]. Because no differences were noted in the mean duration of overall static and dynamic activities from 2 consecutive measurement days, we can conclude that the effect on everyday physical activity of habituation to the monitor can be ignored. No between-day association was noted in the duration of the static activities sitting and lying between different weekdays, whereas these activities were associated on similar weekdays with 1 week in between. This finding was in accordance with our expectations that on similar weekdays similar activities would be performed. This result could indicate that a weekly pattern of physical activity exists. However, in contrast with these findings, no such association was found for standing or walking activities. Between-day variability in activities may be caused by workdays or weekend days, day-specific leisure activities, irregular activities, etc. Such variability implies that the number of days during which measurements must be recorded should increase when sufficient statistical power could be obtained, e.g., when the device is applied in intervention studies.

The findings that similar amounts of walking duration occurred on different days of the same week and the same days of different weeks and that the degree of association between these measures revealed nonsignificant association for day-to-day and week-to-week walking seem contradictory. We think, however, that this finding shows that individual behavior may vary and that comparisons over all subjects obscure such findings. One result that might substantiate this assumption is the rather high individual CVs that we observed for the two postural transitions. Further studies in larger samples that also include analysis on an individual level should determine whether monitoring physical activity in geriatric populations during similar weekdays (e.g., in intervention studies) does or does not reduce the between-day variance of physical activities and/or postural transitions. In this context, we assume that when more senior subjects with a wider range of functioning are measured, different values for daily physical activity will emerge.

An obvious limitation of our study was the rather small sample size. However, information on the variance in everyday physical activity in the geriatric population is essential for assessing the number of activity monitoring days required to describe customary daily physical activity in the target group. In intervention studies with paired comparisons, the between-day variance is particularly important. Based on this variance, the magnitude of the effect one wants to detect, and the available number of subjects, the required number of sampling days can be assessed. This study reveals first estimates for these measures, and further research in larger populations is warranted.

Another limitation of this study was that, although the accuracy of the system that identified the SiSt and StSi was relatively high (more than 82%), it was unable to identify 100 percent of the SiSt and StSi transitions. Therefore, some postural transitions might not be included in **Tables 1** and **2**. In this study, however, we assumed that this missing data did not affect the average TD.

The ability to measure every SiSt and StSi postural transition by an individual within his or her own environment has obvious face validity. In the absence of an accepted gold standard against which to relate a new mobility measure, comparison of the new method with existing measures that are thought to measure a similar construct (physical ability) is appropriate, although very different aspects of mobility may be measured [24]. The significant correlation between FES scores and the mean SiSt TD calculated from 2 consecutive days indicates that the SiSt transition may be a good indicator of actual physical ability in a community setting; this correlation was not present for the StSi transition and walking time.

CONCLUSIONS

We report that physical activity recording with an ambulatory activity monitor with one kinematic sensor attached to the chest and a lightweight, portable data logger carried on the waist was well-tolerated in a sample of geriatric subjects living in a residential care facility. The system offers accurate and reliable measures for the quantification of the SiSt postural transition in a home environment in seniors with a range of confidence in performing daily activities without falling. Levels of activity in the home environment can be quantified, which may aid decision makers in designing physical interventions.

Further studies are warranted to determine the sensitivity of the activity monitor as an outcomes instrument across different populations of older adults (e.g., living independently, living in residential care facilities, or living in nursing homes) and its utility as an evaluative device in rehabilitation programs that investigate falls risk or purport to improve older adults' physical abilities.

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