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Original Report

Smartphone-Based Sit-to-Stand Analysis for Mobility Assessment in Middle Age

Roee Hayek, MSc,[1] Itai Gutman, BSc,[1] Guy Baranes, MSc,[1] Yaniv Nudelman, PhD,[1,2] and Shmuel Springer, PhD[1,*]

[1]The Neuromuscular and Human Performance Laboratory, Faculty of Health Sciences, Department of Physical Therapy, Ariel University, Ariel, Israel.
[2]Maccabi Healthcare Services, Tel-Aviv, Israel.

*Address correspondence to: Shmuel Springer, PhD. E-mail: shmuels@ariel.ac.il

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Abstract

Background and Objectives: Mobility can decline in middle age and growing evidence highlights the importance of assessing mobility at this stage of life. Smartphone-based accelerometry during sit-to-stand has been shown to identify mobility impairments, but its utility in detecting subtle mobility deterioration in middle age has not been tested. This study aimed to examine whether smartphone-based accelerometry data measured during sit-to-stand tests performed on a regular chair and a cushioned sofa could be useful for detecting subtle changes in mobility in middle age.

Research Design and Methods: Twenty-three young (25.0 ± 2.5 years), 25 middle-aged (52.0 ± 5.2 years), and 17 older adults (70.0 ± 4.1 years) performed the 5-times sit-to-stand test on both a standard chair and a sofa. A smartphone attached to the participants' lower back was used to measure lower-limb muscle power, maximal vertical velocity (MVV) during rising, the duration of the total task and the subphase of transition from sitting to standing (SiToSt), and repetition variability using the dynamic time warping method.

Results: Middle-aged adults had reduced lower-limb muscle power compared to young adults (5.25 ± 1.08 vs 6.19 ± 1.38 W/kg, $p = .034$), being more pronounced on the sofa (6.23 ± 1.61 vs 8.08 ± 2.17 W/kg, $p = .004$). Differences between middle-aged and young adults in terms of MVV ($p = .011$) and SiToSt duration ($p = .038$) were only detected on the sofa, and the middle-aged adults showed less variability compared to the older adults on the chair ($p = .018$). There was no difference in total task duration between the middle-aged group and the young or older adults in either condition.

Discussion and Implications: Most common tests are limited in their ability to detect early mobility deterioration in midlife due to a ceiling effect. Our results, which show the potential of smartphone-based sit-to-stand assessment in detecting subtle mobility decline in midlife, could serve as a screening tool for this purpose.

Keywords: Accelerometry, Lower-limb power, Midlife

Translational Significance: A growing body of evidence emphasizes the importance of assessing mobility before the age of 65 to detect "preclinical mobility limitations." A commonly used test to assess mobility is to measure the time it takes a person to complete a 5-times stand-to-stand. However, this type of measurement is not sensitive enough to detect mobility deterioration in midlife. Here, we present the utility of a smartphone accelerometry-based sit-to-stand assessment for detecting subtle mobility deterioration in midlife. This proposed method can be used by clinicians as a screening tool to assess mobility in midlife to implement preventive strategies before deterioration increases.

Middle age is a critical life stage for the detection of early and subtle decrements in mobility associated with aging, and an optimal time for preventive interventions to avoid further deterioration of function (Lachman et al., 2015). One of the most common tests to assess functional decline is the 5-time sit-to-stand (5xSTS), in which subjects are asked to perform five consecutive transitions between sitting and standing. The test scoring is based on the time it takes a person to complete the five repetitions, which is traditionally measured with a stopwatch (Atrsaei et al., 2022; Meulemans et al., 2023). However, this test may not be challenging enough to detect deterioration in mobility in high-functioning older adults or in middle-aged adults who are considered to be better-functioning (Bergquist et al., 2019; Yamada & Demura, 2015).

A more demanding sit-to-stand task may be more effective in identifying subtle changes in mobility associated with aging. The sit-to-stand test is usually performed on a standard-height chair (43–45 cm) with a straight back (Burdett et al., 1985; Roebroeck et al., 1994; Weiner et al., 1993). Lower seating heights, such as park benches in the community, and soft

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seating materials, like cushioned sofas, which are common in homes, can make rising more difficult with age (Alexander et al., 2001; Weiner et al., 1993). Therefore, testing sit-to-stand from lower seat heights with softer materials could increase the ecological validity and utility of the test.

Acceleration and angular velocity data obtained with inertial motion units (IMUs) during sit-to-stand tests have also been proven useful in providing substantial information on mobility, including the duration of subphases of the test (Lummel et al., 2016), and analysis methods like dynamic time warping (DTW) to measure the variability of motor performance (Ghahramani et al., 2020). Several studies have explored the use of sensor-instrumented sit-to-stand to assess mobility in varied populations (Bochicchio et al., 2023; Forero et al., 2023; Ghahramani et al., 2020; Lummel et al., 2016; Meulemans et al., 2023; Tulipani et al., 2022; Van Lummel et al., 2013; Van Roie et al., 2019; Wairagkar et al., 2022; Zijlstra et al., 2010). Sensor-based performance metrics of monitored sit-to-stand transitions have been shown to better identify people with mobility impairments and fall risk than daily living monitoring (Tulipani et al., 2022). Sit-to-stand variability measured using the DTW method significantly differentiated between older fallers and nonfallers, with high sensitivity and specificity (Ghahramani et al., 2020). Overall, these studies suggest that acceleration data from sit-to-stand tests can provide valuable information for detecting mobility deterioration.

Another key outcome that can be measured with instrumented IMU sit-to-stand is lower-limb muscle power (STSp; Atrsaei et al., 2022; Meulemans et al., 2023), by multiplying body mass, acceleration, and velocity during the rising phase (Atrsaei et al., 2022; Meulemans et al., 2023; Van Roie et al., 2019). Atrsaei et al. (2022) tested older adults during instrumented IMU sit-to-stand and found that fallers exhibited lower STSp than nonfallers. Van Roie et al. (2019) reported lower STSp during sit-to-stand in older adults compared to young and middle-aged adults. Meulemans et al. (2023) found that older subjects and women had lower STSp compared to younger subjects and men. Older adults with impaired function had reduced STSp compared to their well-functioning counterparts. Given that age-related decline in lower-limb muscle power occurs earlier and more rapidly than the decline in muscle force or mass, it can be better used to detect early changes in mobility (Strotmeyer et al., 2018; Van Roie et al., 2018).

In recent years, smartphones have been increasingly used to assess human mobility, including sit-to-stand (Harari et al., 2017; Straczkiewicz et al., 2021). The use of smartphones to detect mobility decline during aging has significant applicability and utility advantages (Straczkiewicz et al., 2021). Smartphones are ubiquitous, inexpensive, and equipped with accelerometers and gyroscopes that can capture relevant data on movement patterns (Amez & Baert, 2020; Song et al., 2021).

The aim of this study was therefore to investigate whether accelerometry data during a sit-to-stand test measured with a smartphone could be useful to detect subtle changes in mobility in middle-aged adults. We hypothesize that performing sit-to-stand from a sofa will have a greater effect on movement characteristics in middle-aged and older adults than in young adults. Particularly, we hypothesize that STSp and the maximal velocity during rising from a sofa will be sensitive indicators of mobility deterioration in middle-aged adults.

Method

Participants

The study included a sample of independent community-dwelling adults, 23 young adults (20–40 years old), 25 middle-aged adults (45–64 years old), and 17 older adults (65–85 years old). Our primary analysis focuses on comparing middle-aged with young adults, whereas older adults serve as a reference group to provide context for performance at older ages. Previous studies comparing middle-aged with young adults (Hayek et al., 2022; Naaman et al., 2023) have shown that a sample size of at least 20 subjects in the middle-aged and young adults groups would be sufficient to detect potential differences in performance. Furthermore, a power analysis using G*power 3.1.9 (Faul et al., 2007) for the one-way ANOVA estimated at 0.8 with alpha = 0.05 and large effect size ($f = 0.4$) indicated that a total sample size of $n = 64$ in the three groups would be needed to detect the main effect.

Participants were included if they lived in the community, were independent in activities of daily living, and could walk without assistance. Subjects with neurological (e.g., multiple sclerosis, Parkinson's disease, and stroke), orthopedic (e.g., hip/knee replacement/arthroplasty, ankle arthrodesis, and back surgery in the last year), vestibular, or visual impairments (e.g., age-related macular degeneration, glaucoma, cataract, and diabetic retinopathy) or other comorbidities that could affect mobility were excluded. All participants were recruited through public advertising in the community and on social media. The target population included university students and employees as well as residents of the local university town. Candidates were screened by telephone to determine their eligibility for the study. The study was approved by Ariel University Ethics Committee (approval number AU-HEA-SS-20230806). All subjects gave written informed consent to participate in the study.

Procedure

Before the sit-to-stand assessment, standard anthropometric data were measured (i.e., height [m] and weight [kg]) and body mass index (BMI, kg/m^2) was calculated. 5xSTS was tested in a randomized order in two sitting positions: on a standard chair (height = 0.46 cm, depth = 0.45 cm, Figure 1A) and on a cushioned sofa (height = 0.40 cm, depth = 0.50 cm, Figure 1A). Participants were asked to perform five repetitions of standing up as quickly as possible from the seated position to a fully standing position without using the hands (arms crossed over the chest) and then return to the seated position (Bohannon et al., 2007; Paul & Canning, 2014). The test was performed twice, preceded by one or two sit-to-stand repetitions for familiarization to ensure that the subject understood the instructions. There was a 2-min break between the familiarization and the measurements, and each measurement was followed by a 15-s rest period. For each subject, the trial with the shortest total duration (s) was included in the analysis (Meulemans et al., 2023).

Measuring Equipment

A smartphone (Model Galaxy A73; Android 13; 163 × 76.1 × 7.6 mm; 181 g) was positioned in an elastic belt at the middle of the lumbar spine of each subject during the test so that it was close to the body's center of mass (Figure 1B). This position has been validated and proven reliable for analyzing sit-to-stand outcomes (Abou et al., 2021; Mansson et al., 2021; Marques et al., 2021; Serra-Añó et al., 2019). The data were recorded using the phyphox application (RWTH Aachen, Germany) with a sampling rate of 100 Hz, which is a reliable method for measuring acceleration during movement, allowing remote control via Wi-Fi, as shown in Figure 1B (Staacks et al., 2018; Your Smartphone Is a Mobile Lab., n.d.).

Data Processing

Signal processing and parameter extraction were performed using MATLAB (Mathworks, Inc.; version 9.12). The vertical acceleration signal was filtered with a 4th-order Butterworth low-pass filter with a cutoff frequency of 3 Hz (Regterschot et al., 2014). The vertical velocity (m/s) was calculated by integrating the vertical acceleration signal (m/s^2). Based on the vertical velocity, the five cycles of the sit-to-stand were recognized and each cycle was divided into four defined sub-phases, transition from sitting to standing (SiToSt), standing (Stand), transition from standing to sitting (StToSi), and sitting (Sit) as previously described (Bochicchio et al., 2023; Van Lummel et al., 2013), and presented in Figure 2. Time points of the maximum (Max) and minimum (Min) peaks of the vertical velocity have been identified, as well as the times at which the vertical velocity crossed zero. Sit was defined as the time duration between the Min peak to the next zero crossing; SiToSt was defined between the zero crossing in the positive direction to the next Max peak; Stand was defined between the Max peak to the next zero crossing in the negative direction; StToSi was defined between the zero crossing to the next Min peak in the negative direction.

STSp (*W*) was calculated as the subject's body mass (kg) multiplied by the vertical acceleration (a_v + 9.81 m/s^2) multiplied by the vertical velocity (v_v) measured during SiToSt, according to the following formula (Zijlstra et al., 2010):

$$\text{Power } [W] = \text{Body mass } [\text{kg}] \cdot (a_v + 9.81) \ [\text{m/s}^2] \cdot v_v \ [\text{m/s}]$$

The STSp (*W*) was normalized (divided by) to the subjects' body weight (STSpn, W/kg; Cerrito et al., 2015; Meulemans et al., 2023). To analyze the maximal velocity during rising the mean value of maximal vertical velocity (MVV) during SiToSt was calculated (m/s). Duration outcomes (s) included the total duration of the five cycles and the average duration of the SiToSt sub-phase to allow for a more detailed analysis of the subphase of the movement in which concentric power is generated. DTW

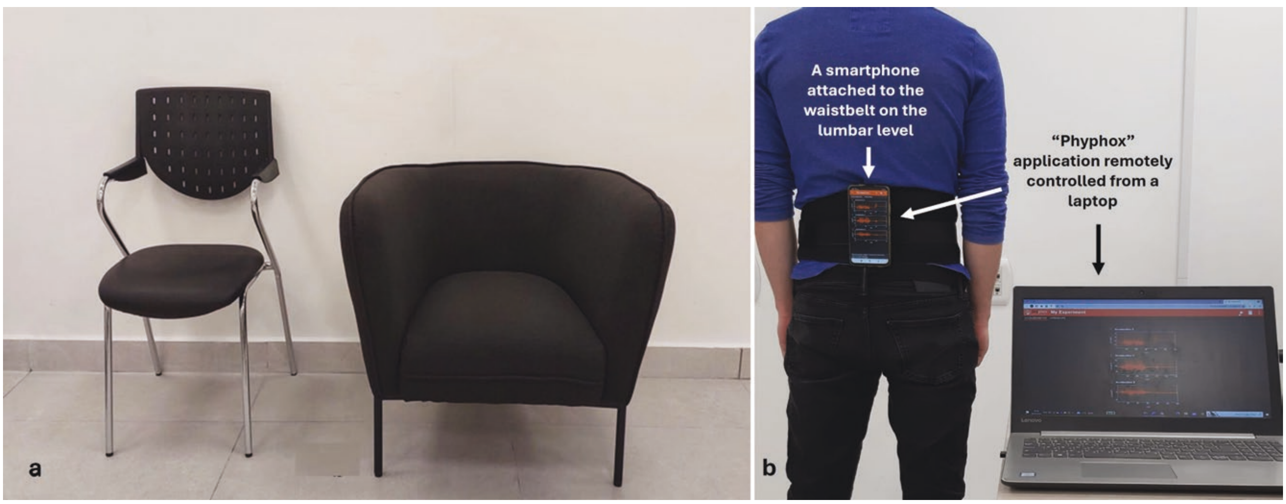

Figure 1. The two seats in the sit-to-stand test and the smartphone location.

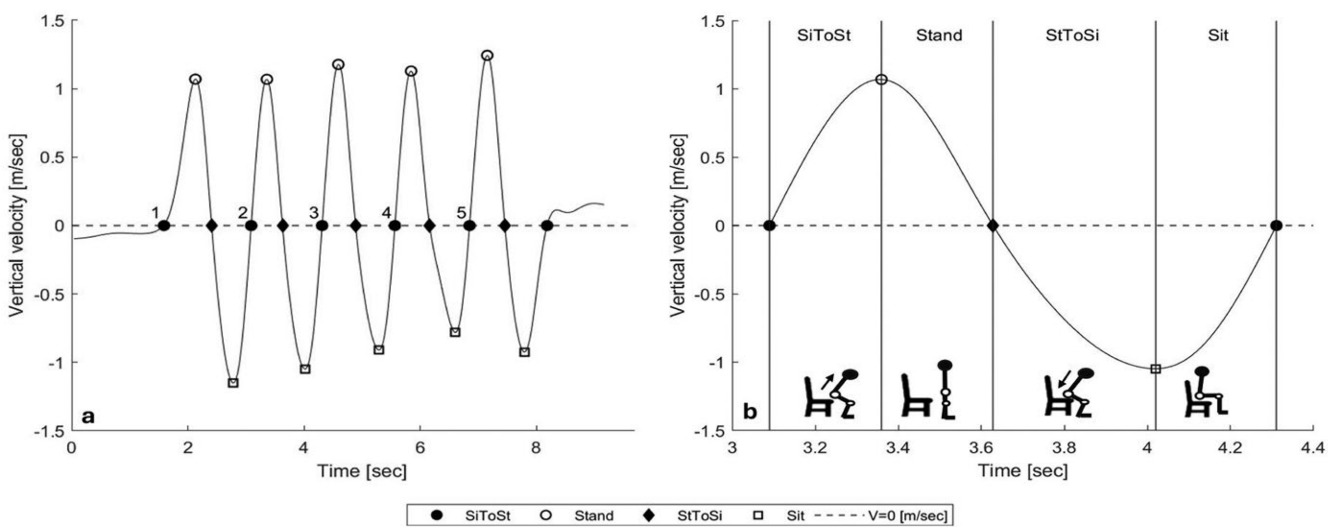

Figure 2. The recognition of the sit-to-stand cycles and the four sub-phases in each cycle.

was used to analyze variability, comparing all combinations of the five repetitions (cycles) (Ghahramani et al., 2020), with smaller values of DTW indicating greater similarity and less variability between signals. The analysis was performed in the same way for the measurements on the chair and the sofa, with all variables also being analyzed for both conditions.

Statistical Analysis

Normal distribution was assessed using the Shapiro–Wilk test and histograms. Quantitative variables were summarized for descriptive statistics using mean and standard deviation (*SD*) or median and interquartile range, depending on the distribution. Categorical variables were presented as frequencies and percentages.

Participant characteristics (e.g., gender, height [m], and weight [kg] and dependent variables (STSpn [W/kg], MVV [m/s], sit-to-stand duration outcomes [s], and DTW for both chair and sofa conditions) were compared between age groups using either one-way analysis of variance (ANOVA) or the Kruskal–Wallis test. ANOVA was chosen when the assumptions of normal distribution and homogeneity of variances (Levene's test) were met. Post hoc analysis was conducted using Scheffé's method or pairwise comparisons with Bonferroni correction for multiple comparisons. The effect sizes (ES) for the between-group differences were interpreted using Cohen's d, categorized as small ($d = 0.2$), medium ($d = 0.5$), and large ($d = 0.8$; Cohen, 1988), and Spearman's rho, categorized as small ($r = 0.2$), medium ($r = 0.4$), and large ($r = 0.8$; Rea & Parker, 2014), for parametric and nonparametric measures, respectively. Statistical analysis was performed using IBM SPSS Statistics, version 27.0. (Armonk, NY: IBM Corp). Significance was set at $p < .05$.

Results

Participant Characteristics

Participants' characteristics are shown in Table 1. No significant differences were found between the groups.

Power During SiToSt

Significant differences between age groups were observed in lower-limb power normalized to body weight (W/kg) in both the chair and sofa conditions (chair: $F(2, 62) = 10.427$, $p < .001$; sofa: $F(2, 62) = 11.703$, $p < .001$). Post hoc analysis revealed that young participants had significantly greater STSpn values compared to middle-aged participants in the chair condition (mean difference = 0.94 W/kg, $d = 0.75$, $p = .034$), with the difference being even more pronounced in the sofa condition (mean difference = 1.85 W/kg, $d = 0.97$, $p = .004$). Similarly, a significant difference was found between young and older adult groups in the chair condition (mean difference = 1.76 W/kg, $d = 1.36$, $p < .001$), which increased in magnitude in the sofa condition (mean difference = 2.67 W/kg, $d = 1.37$, $p < .001$). These results are summarized in Table 2 and also presented in Figure 3.

Maximal Velocity During SiToSt

Maximal vertical velocity (MVV, m/s) comparison between groups showed a significant difference under both chair and sofa conditions (chair: $F(2, 62) = 6.381$, $p = .003$, sofa: $F(2, 62) = 16.223$, $p < .001$), as shown in Table 2. The post hoc analysis revealed no difference between young and middle-aged subjects under the chair condition ($d = 0.45$, $p = .323$), whereas a significantly lower MVV with a large effect size was observed in the middle-aged group under the sofa condition ($d = 0.90$, $p = .011$). Older adults had significantly lower MVV values compared to young adults under both the chair and sofa conditions ($d = 1.31$, $p = .003$ and $d = 1.47$, $p < .001$, respectively). There were no significant differences between middle-aged and older adults in either condition (see Table 2 and Supplementary Figure 1).

Sit-to-Stand Duration Outcomes

A significant difference between groups in the total sit-to-stand duration (s) was found in both chair and sofa conditions (chair: $H(2) = 10.512$, $p = .005$, sofa: $H(2) = 11.473$, $p = .003$). Pairwise comparisons showed that the participants in the young group performed the task faster in the chair and sofa conditions than the older adults ($r = -0.51$, $p = .004$, and $r = -0.52$, $p = .003$, respectively). The middle age group did not differ from the young or older adults in either condition. A significant difference between groups was also found in the median duration of the SiToSt subphase under both the chair and the sofa conditions (chair: $H(2) = 13.006$, $p = .001$, sofa: $H(2) = 10.088$, $p = .006$), as shown in Table 2. Pairwise comparisons demonstrated significant differences between young and middle-aged groups only in the sofa condition (chair: $r = -0.33$, $p = .064$, sofa: $r = -0.35$, $p = .038$) and between young and older adults in both conditions (chair: $r = -0.55$, $p = .001$, sofa: $r = -0.41$, $p = .011$; see Table 2 and Supplementary Figure 2). There were no significant differences between middle-aged and older adults in either condition.

Dynamic Time Warping

The Kruskal–Wallis tests used to compare DTW of vertical velocity between groups showed a significant difference only in the chair condition ($H(2) = 8.202$, $p = .017$). Post hoc analysis revealed that the middle-aged group had less variability compared to the older adults in the chair condition ($r = -0.42$,

Table 1. Participants' Characteristics

Variable	Young adults ($n = 23$)	Middle-aged adults ($n = 25$)	Older adults ($n = 17$)	p Value
Age (years), Mean ± *SD*	25.0 ± 2.5	52.0 ± 5.2	70.0 ± 4.1	<.001
Gender: Female, *n* (%)	13 (56%)	13 (52%)	8 (47%)	.841
Height (m), Mean ± *SD*	1.69 ± 0.1	1.65 ± 0.1	1.68 ± 0.8	.372
Weight (kg), Mean ± *SD*	70.5 ± 14.2	71.3 ± 13.8	75.0 ± 8.6	.528
Body mass index (kg/m^2), Mean ± *SD*	24.3 ± 3.1	25.8 ± 3.7	26.3 ± 2.7	.129

Note: *SD* = standard deviation.

Table 2. Sit-to-Stand Outcomes Measures Between Age Groups With Post Hoc Analysis

Measure	Condition	Young adults (n = 23)	Middle-aged adults (n = 25)	Older adults (n = 17)	Between groups p value	Young adults vs middle-aged adults			Middle-aged adults vs older adults			Young adults vs older adults		
						ES	*SE*	p Value	ES	*SE*	p Value	ES	*SE*	p Value
Power normalized (W/kg)[a]	Chair	6.19 ± 1.38	5.25 ± 1.08	4.43 ± 1.15	<.001	0.75	0.35	.034	0.74	0.38	.107	1.36	0.38	<.001
	Sofa	8.08 ± 2.17	6.23 ± 1.61	5.41 ± 1.58	<.001	0.97	0.52	.004	0.51	0.57	.364	1.37	0.58	<.001
MVV (m/s)[a]	Chair	0.86 ± 0.16	0.79 ± 0.14	0.68 ± 0.14	.003	0.45	0.04	.323	0.76	0.04	.090	1.31	0.04	.003
	Sofa	1.02 ± 0.16	0.87 ± 0.15	0.77 ± 0.15	<.001	0.90	0.04	.011	0.64	0.05	.166	1.47	0.05	<.001
Total duration (s)[b]	Chair	7.51 (6.27–8.25)	7.81 (7.12–9.21)	8.44 (7.93–11.39)	.005	−0.25	—	.219	−0.25	—	.305	−0.51	—	.004
	Sofa	7.62 (5.69–8.29)	8.04 (7.29–9.73)	8.73 (7.84–12.12)	.003	−0.31	—	.087	−0.21	—	.518	−0.52	—	.003
SiToSt (s)[b]	Chair	0.37 (0.32–0.41)	0.45 (0.36–0.51)	0.49 (0.39–0.66)	.001	−0.33	—	.064	−0.22	—	.415	−0.55	—	.001
	Sofa	0.33 (0.30–0.38)	0.41 (0.34–0.51)	0.45 (0.32–0.62)	.006	−0.35	—	.038	−0.1	—	1	−0.41	—	.011
DTW[b]	Chair	1.47 (0.89–2.15)	1.1 (0.74–1.43)	1.63 1.16–2.35)	.017	−0.28	—	.156	−0.42	—	.018	−0.15	—	1
	Sofa	1.48 (1.08–2.73)	1.49 (1.05–2.16)	1.84 (1.45–3.27)	.147	−0.07	—	1	−0.30	—	.163	−0.22	—	.466

Notes: DTW = dynamic time warping; ES = effect size; MVV = maximal velocity in vertical movement; *SE* = standard error; SiToSt = transition from sitting to standing.
Superscript used to show pairwise comparisons using post hoc analysis between age groups using either one-way analysis of variance (ANOVA) or the Kruskal–Wallis test.
[a]Parametric variables—Mean ± standard deviation, one-way ANOVA used for between-age groups comparison, effect size (d) used was Cohen's d, and p values adjusted by Scheffe.
[b]Nonparametric variables—Median (interquartile range), Kruskal–Wallis test used for between age groups comparison, the effect size (r) used was Spearman's rho, and p values adjusted by Bonferroni.

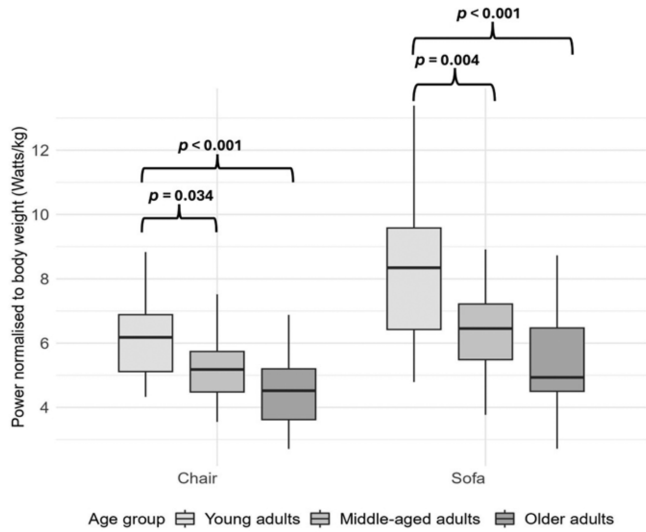

Figure 3. Lower limb power across conditions and age groups.

p = .018). No other differences were found. DTW of vertical velocity results are represented in Table 2.

Discussion and Implications

This study examined the utility of smartphone-based sit-to-stand assessment in detecting mobility decline in middle age. Our findings suggest that smartphone IMU-derived measures, such as power and maximal rising velocity, may identify subtle changes in mobility performance in this population.

Both middle-aged and older adults had lower muscle power values than young adults. The age-related decline in lower-limb muscle power demonstrated in our study and supported by existing research (Alcazar, Alegre, et al., 2021; Meulemans et al., 2023) has implications on mobility and many other daily functions (Cruz-Jimenez, 2017), and is associated with a higher risk of falls (Alcazar, Aagaard, et al., 2021; Benichou & Lord, 2016; Cruz-Jimenez, 2017; Meulemans et al., 2023). Accurate and accessible assessment of lower-limb muscle power across the lifespan may be of great benefit in identifying risk factors and formulating appropriate treatment plans (Campitelli et al., 2022; Meulemans et al., 2023).

We have shown that smartphones, which have become an integral part of people's lives (Statista, 2021), can be used to provide sufficient and accurate information on lower-limb muscle power in middle age. As such, they offer a cost-effective alternative to the use of specialized and complicated technologies often used in mobility research, particularly in the lower-limb muscle power assessment (Abou et al., 2021; Amez & Baert, 2020; Song et al., 2021). This is the first study that utilized smartphone-based sit-to-stand analysis to assess mobility in middle-aged adults. Our findings should encourage future studies, particularly those implementing smartphone-based sit-to-stand analysis in clinical and home settings with varied and different seats.

The lower-limb power values of the three age groups in the present study are similar to the power norms reported by Campitelli et al. (2022) and are consistent with a previous study that found a significant decline in sit-to-stand power over the age of 45 years (Meulemans et al., 2023). In contrast, Van Roie et al. (2019) examined sit-to-stand power in young, middle-aged, and older adults and found decreased power only when comparing older adults with the other age groups. A possible explanation for the different results could be related to the method used to analyze lower-limb power. The calculation of lower-limb power during sit-to-stand is partially based on body mass. Because body mass tends to be lower in young adults than in middle-aged adults (Alcazar, Aagaard, et al., 2021), power should be normalized to the subjects' body weight before comparing between age groups.

We found a lowered maximal velocity during rising in middle-aged individuals compared to young adults under the sofa condition only. The lowered MVV may indicate that middle-aged individuals stand up less explosively than young adults (Janssen et al., 2002). The ability to generate explosive force is essential to overcome sudden disturbances during ambulation (Dahlin, 2018). Several factors may contribute to lower MVV during rising, including age-related declines in muscle strength, difficulties in rapidly generating the force, and an impaired ability to adapt to more demanding tasks (Bochicchio et al., 2023; Mak & Hui-Chan, 2005; Meulemans et al., 2023; Naaman et al., 2023).

Our results indicate no difference in the sit-to-stand total duration between middle-aged adults compared to the young and older adult groups in both conditions. These results are in contrast to previous studies that reported differences in sit-to-stand total duration between young and middle-aged adults measured with body-worn sensors (Meulemans et al., 2023; Van Roie et al., 2019). Nevertheless, our results of sit-to-stand duration are very similar to those reported in one of these two studies (Van Roie et al., 2019), in both the young (7.14 s compared to 7.86 s) and middle-aged groups (8.14 s compared to 8.47 s). This may enhance the understanding that mobility deterioration in middle age cannot be based solely on the completion time of sit-to-stand and additional outcomes should be considered.

The middle-aged adults showed increased SiToSt duration in the sofa condition compared to young adults, whereas differences were found between young and older adults in both conditions. This finding supports our hypothesis that getting up from a sofa instead of a normal chair is better at detecting mobility deterioration in middle-age, and is consistent with Van Roie et al. (2019), who noted that reducing seat height in adults with good functionality could help detect age-related changes. Older adults have decreased reliance on knee extensors and increased engagement of hip extensors during the SiToSt phase (Meulemans et al., 2023). Although we observed lower power values in middle-aged and older adults compared to young adults both on the chair and on the sofa, the differences were more pronounced on the sofa. It can be suspected that the longer SiToSt duration on the sofa in the middle-aged group is related to reduced lower-limb power compared to young adults. The prolonged SiToSt duration and decreased MVV in the middle-aged group on the sofa suggest that this condition was more demanding, supporting the notice that more strenuous tasks are required to accurately capture subtle functional changes in middle-aged adults (Naaman et al., 2023). Furthermore, it has been shown that the height of public seating in the community can vary by up to 15 cm (30.5 to 45.7 cm; Weiner et al., 1993). This increases the ecological validity of our results, which examined sit-to-stand performance at two different seat heights and materials.

This is the first study to compare the variability of sit-to-stand velocity between three different age groups. Under the chair condition, middle-aged had lower variability than older adults, whereas surprisingly no significant differences were found between young and older adults. A possible explanation may lie in the differences between skilled and unskilled performers (Jarus & Goverover, 1999; Raviv et al., 2022). Older adults may represent unskilled performers who exhibit high variability with reduced performance, whereas young adults may represent the experts who exhibit high variability with good performance. The middle-aged adults, who showed lower variability compared to the older adults, may be considered partially skilled performers who tend to focus on the task and show lower performance variability (Jarus & Goverover, 1999). It is possible that no differences were observed on the sofa because the middle-aged adults had difficulty keeping variability low on a more demanding task. Further research that will examine the effects of age on sit-to-stand performance is warranted.

This study has several limitations that should be carefully considered. The observed nonsignificant differences should be interpreted with caution. The sample size of the study was designed to detect large effects. In midlife, human performance can vary greatly from person to person, potentially masking more nuanced age-related changes. In addition, the exclusion of participants with different medical conditions could limit the generalizability of the results. Future research with larger and more diverse samples could provide more robust results and allow a more detailed analysis of subtle deterioration in mobility in middle age. However, it is important to note that the finding of performance deterioration in our high-functioning sample suggests that such results may be even more pronounced in a more heterogeneous sample of middle-aged adults. Furthermore, the protocol included a different number of repetitions for familiarization (one or two), and the best measure from two trials was used for the analysis. Although these approaches might have affected the robustness of the data, they allowed for a more flexible and realistic assessment that has been used extensively in similar studies (Meulemans et al., 2023; Van Roie et al., 2019). Finally, although the results show a trend toward greater difficulty in rising from the sofa from middle age onwards, the comparison of the different seats was beyond the scope of this study; therefore, no appropriate statistical model was used. In addition, the firmness of the seat of varied sofa types can strongly influence the ability to stand up. Our results should encourage future research focusing on the effects of standing up from different seat heights and materials.

Our findings demonstrate the utility of a smartphone-based sit-to-stand assessment for detecting subtle declines in mobility performance in midlife and may serve as a practical tool to support the emerging evidence emphasizing the importance of assessing mobility before the age of 65. The presence of differences with large effect sizes between middle-aged and young adults without major differences between middle-aged and older adults suggests that changes in mobility tasks may occur as early as middle age. Physical performance does not necessarily decline linearly with age, and midlife can be a crucial key stage for mobility skills. The use of smartphone accelerometry-based sit-to-stand assessment for detecting subtle mobility deterioration in midlife can be used by clinicians as a screening tool to assess mobility in midlife to proactively address these changes and potentially improve quality of life in later years.

Supplementary Material

Supplementary data are available at *Innovation in Aging* online.

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Conflict of Interest

None.

Data Availability

Data and material assessed in this study can be requested by contacting the corresponding author. The study reported in the manuscript was not preregistered.

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