Journal of Electromyography and Kinesiology 90 (2026) 103198

Contents lists available at ScienceDirect

Journal of Electromyography and Kinesiology

journal homepage: www.elsevier.com/locate/jelekin

Insights into functional mobility in older adults from the instrumented timed up and go (iTUG): a retrospective study

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ARTICLE INFO

Keywords:
Functional mobility
Aging
Instrumented timed up and go
Inertial measurement unit
Older adults
Functional decline

ABSTRACT

This retrospective study aimed to examine age-related differences in functional mobility across narrowly defined age groups of community-dwelling older adults using the instrumented Timed Up and Go (iTUG) test. Specifically, we sought to identify which iTUG subtasks and sensor-derived parameters showed the most pronounced differences across age strata and to characterize phase-specific temporal and kinematic features from 65 years onward using a single-sensor approach. We hypothesized that age-related differences would not affect all iTUG components uniformly, with walking and turning-related parameters showing clearer differences across age groups than trunk excursion measures.

Data from 212 healthy adults aged over 65 years were retrospectively analyzed and stratified into four age groups. Functional mobility was assessed using a single lumbar-mounted inertial measurement unit (IMU) during the iTUG. Primary outcomes included total and sub-phase durations (sit-to-stand, walking, turning, stand-to-sit), turning velocities, and trunk flexion/extension angles during postural transitions. Between-group differences were assessed using MANOVA followed by Bonferroni-adjusted ANOVAs. A significant main effect of age group was found for iTUG parameters ($p < 0.001$, $\eta^2 = 0.13$). Total duration and most sub-phase durations increased across age groups, whereas no significant age-group differences were observed in trunk flexion or extension angles. These findings indicate that temporal and velocity-based iTUG parameters, especially those related to walking and turning, showed clearer age-stratified differences than trunk angular measures. Overall, the study provides descriptive age-stratified data on phase-specific iTUG features in community-dwelling older adults and supports the value of subtask-level analysis for characterizing functional mobility beyond total TUG duration alone.

1. Introduction

The physiological aging process is associated with changes in musculoskeletal and cognitive function, which may affect mobility-related tasks, essential for daily living (Jost and Kujach, 2025; Sui et al., 2020). In fact, decreased muscle strength, joint mobility, impairment in sensory function (i.e., sight, hearing, proprioception), and the presence of chronic conditions (Chase et al., 2016) impact both fine and gross motor skills (Seidler et al., 2010; Hoogendam et al., 2014), contributing to decrease the efficiency of fundamental tasks such as walking (Lajoie et al., 1996; Pau et al., 2023), turning (Mancini et al., 2016), and postural transitions (Chimsuwan et al., 2024). In particular, gait instability and impaired postural control increase the risk of falls, a major concern for older adults due to its physical, psychological, and socio-economic consequences (Salvà et al., 2004; Milat et al., 2011). This highlights the importance of reliable mobility screening tools able to characterize functional mobility performance and support timely and targeted interventions aimed at preserving autonomy and overall well-being in aging populations.

The Timed Up and Go (TUG) test is a widely utilized clinical tool for

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https://doi.org/10.1016/j.jelekin.2026.103198
Received 27 November 2025; Received in revised form 4 August 2026; Accepted 9 August 2026
Available online 10 August 2026

assessing functional mobility, balance, and fall risk in older adults (Podsiadlo and Richardson, 1991; Kear et al., 2017). Its simplicity and minimal equipment requirements make it practical for use across various clinical and community settings. During the test, the individual is timed while standing up from chair, walking three meters, performing a 180° turn, walking back, performing a second 180° turn and sitting down. By integrating key motor tasks largely adopted for daily living mobility purposes (i.e., gait, turning, and postural transitions), the TUG provides a globalmeasure of functional mobility, with longer test completion times generally associated with poorer mobility performance (Beauchet et al., 2011; Najafi et al., 2002). Although the TUG is easy to administer, its traditional assessment relies primarily on total completion time measured by a stopwatch, without providing detailed information on the performance of its individual sub-phases (Salarian et al., 2010).

To overcome these limitations, instrumented versions of the TUG (iTUG) have been proposed. By using one or more compact and lightweight wearable Inertial Measurement Units (IMUs), it is possible to collect high-resolution kinematic data, including acceleration, angular velocity, and orientation of body segments across multiple axes (Wang et al., 2023; Cuesta-Vargas et al., 2010). Moreover, this approach allows segmenting the TUG into its functional sub-tasks (e.g., sit-to-stand, walking, turning, and stand-to-sit), thus enabling the extraction of phase-specific parameters including sub-phase durations, gait speed, turning velocity, and trunk angles. By segmenting the TUG into its functional sub-phases and extracting phase-specific parameters, the iTUG may provide further insight into specific mobility domains, such as postural transitions, gait, and turning, that may not be captured by total completion time alone. In addition, the iTUG provides a more objective and standardized alternative to manual timing, reducing operator variability and supporting its application in both research and clinical settings (Greene et al., 2010; van Lummel et al., 2016; Cimolin et al., 2019; Zampieri et al., 2010).

A growing body of research supports the utility of the iTUG for providing a detailed characterization of functional mobility in older adults and clinical populations (Szaflik and Nowakowska-Lipiec, 2026; Böttinger et al., 2024). By enabling the segmentation of the test into distinct subtasks and the extraction of phase-specific temporal and kinematic parameters, wearable sensors have demonstrated additional value compared with traditional stopwatch-based assessment (Salarian et al., 2010; Mulas et al., 2021; Kleiner et al., 2018; Szaflik et al., 2026). In particular, sensor-derived measures related to gait and turning, including gait speed, step time variability, turn duration, and turning velocity, have been associated with cognitive impairment and fall risk and may provide clinically relevant information beyond total TUG completion time (Greene et al., 2014; Sample et al., 2017; Ortega-Bastidas et al., 2023; Zakaria et al., 2015; Brauner et al., 2021; Hellmers et al., 2018; Mangano et al., 2020). However, less is known about which specific iTUG subtasks and sensor-derived parameters show the most pronounced differences across narrowly defined age strata in healthy community-dwelling older adults.

Therefore, the aim of this study was not to further validate IMU-based TUG assessment, but rather to investigate age-related differences in specific iTUG components across narrowly defined age groups of community-dwelling older adults. Specifically, we aimed to identify which iTUG subtasks and parameters show the most sensitive differences across age strata and to characterize phase-specific temporal and kinematic iTUG features from 65 years onward using a pragmatic single-sensor approach.

We hypothesized that age-related differences would not affect all iTUG components uniformly, and that walking and turning-related temporal and velocity parameters would show clearer age-group differences than trunk excursion measures during postural transitions.

2. Materials and methods

2.1. Participants

This retrospective study analyzed data from an existing anonymized dataset collected between November 2019 and June 2025 on community-dwelling older adults who had been evaluated at University of Cagliari (Cagliari, Italy) and Politecnico di Milano (Milan, Italy). The study protocol complied with the Declaration of Helsinki (1964) and its subsequent revisions and received approval from the ethics committees of both institutions. Written informed consent was obtained from all participants prior to their inclusion in the original data collection. Eligibility criteria were as follows: (1) age > 65 years (2) ability to walk independently, without the use of walking aids or human assistance; (3) absence of orthopaedic or neurologic conditions able to severely compromise mobility, as well as no spinal disorders that might affect sensor's placement; (4) preserved cognitive function (i.e. MMSE score > 24) (Magni et al., 1996); and (5) absence of depressive symptoms (i.e. score on 30-item Geriatric Depression Scale >10).

A total of 212 (119 males and 93 females) individuals who met the inclusion criteria were included in the study and stratified into four groups (Buehler et al., 2024) as follows:

- Group 1 (age 65–69 years, $n = 29$; 2 males, 27 females)
- Group 2 (age 70–74 years, $n = 71$; 50 males, 21 females)
- Group 3 (age 75–79 years, $n = 63$; 39 males, 24 females)
- Group 4 (age ≥ 80 years, $n = 49$; 28 males, 21 females)

Their anthropometric features are reported in Table 1.

2.2. Data collection

All measurements were conducted under standardized laboratory conditions using a single wearable IMU (G-Sensor®, BTS Bioengineering, Italy). The IMU integrated a tri-axial accelerometer and a tri-axial gyroscope, both with 16 bit/axes resolution and adjustable sensitivity ranges, and a 143-bit (± 1200 mT) tri-axial magnetometer. Data were collected at a sampling frequency of 100 Hz and transmitted via Bluetooth to a laptop for processing. A dedicated software package (G-Studio, BTS Bioengineering S.p.A.; version 3.2.20) was used to manage data acquisition, processing, reporting and storage. The software included a specific protocol for analyzing the iTUG test, which automatically generated a report containing test-specific parameters. Before starting the test, the sensor was positioned over the lower back at the L2 vertebra level using an elastic belt, whose tightness was adjusted for each participant to ensure comfort and stability to avoid undesired sensor misalignments throughout the test (Fig. 1a). In agreement with previous literature (Szaflik and Nowakowska-Lipiec, 2026; Mangano et al., 2020; Weiss et al., 2011), a single lumbar-mounted IMU was chosen as it provides a minimally invasive and comfortable setup,

Table 1
Anthropometric features of participants. Values are expressed as mean ± standard deviation (SD), except for the number of participants, which is divided into males (M) and females (F) for each group.

	Group 1 (65–69 years)	Group 2 (70–74 years)	Group 3 (75–79 years)	Group 4 (age ≥ 80 years)
Participants # (M/F)	29 (2/27)	71 (50/21)	63 (39/24)	49 (28/21)
Age (years)	68.01 ± 1.56	72.53 ± 1.40	77.79 ± 1.45	82.65 ± 2.68
Body Mass (kg)	60.72 ± 10.78	65.14 ± 12.14	63.77 ± 11.21	65.72 ± 11.12
Height (cm)	159.24 ± 6.83	158.96 ± 12.55	161.12 ± 7.33	160.98 ± 8.86

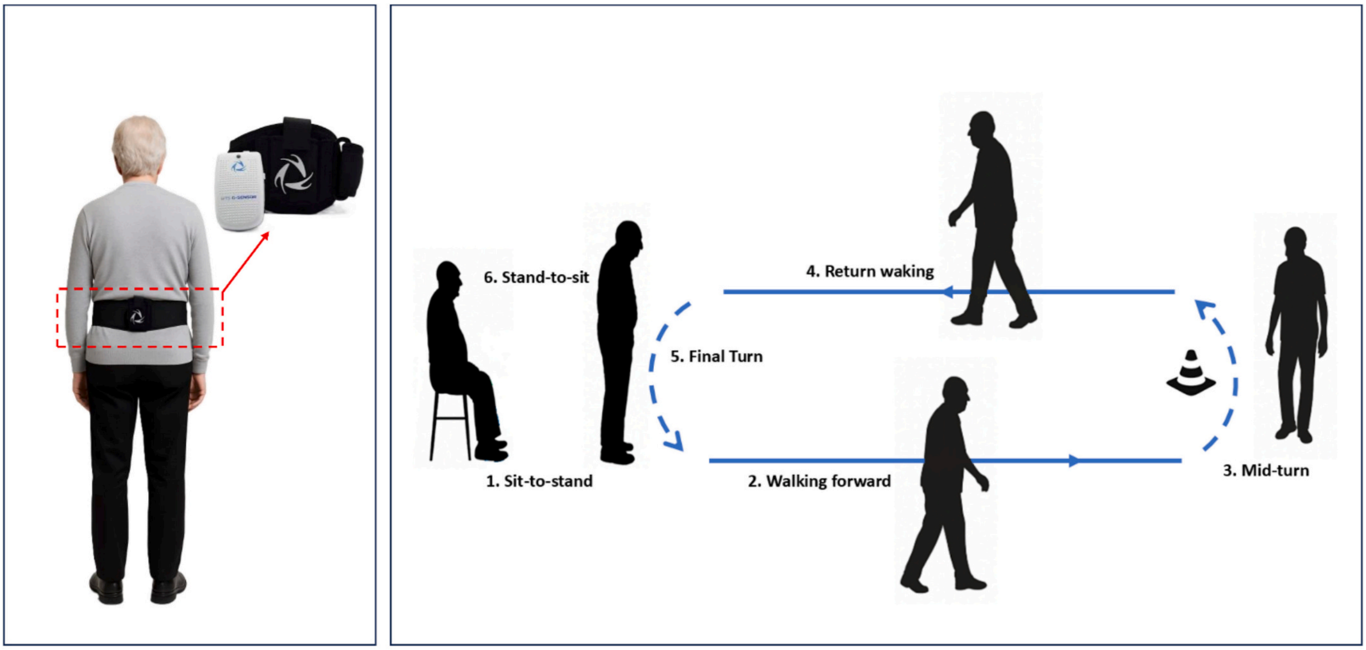

Fig. 1. Experimental setup and test sequence. (a) Detail of the IMU-based device used in this study. The sensor unit is inserted into a dedicated pocket on the elastic belt and positioned at the lumbar level (L2 vertebra). (b) Illustration of the iTUG test sequence. The test consists of six sequential subphases: (1) Sit-to-stand transition from a seated position; (2) Walking forward along a 3 m straight path; (3) Mid-turn around a cone; (4) Return walking toward the chair; (5) Final turn to face the chair; and (6) Stand-to-sit transition.

ensuring a reliable and clinically feasible assessment.

After sensor setup, participants sat on a standard chair without armrests, with their feet flat on the floor and their arms at their sides, and they received the following standardized instructions: “When I say ‘Go’, I want you to stand up from the chair, walk straight ahead at your normal pace, turn around, and then walk back to the chair, turn around, and sit down”. Additionally, they were asked not to use their upper limbs to assist the sit-to-stand and stand-to-sit transitions**.** At the verbal cue (“Go”), participants started the movement by rising from the chair (sit-to-stand sub-phase), walking forward over a distance of 3 m marked by a cone (walking forward sub-phase), passing the cone and turning around it (mid-turning sub-phase), returning along the same 3-m path (return walking sub-phase), turning to face the chair (final turning sub-phase), and sitting back down (stand-to-sit sub-phase) (Thigpen et al., 2000) **(**Fig. 1b**)**. The test was considered complete when the participant had returned to a seated position. The turning point was standardized using a cone placed at the end of the 3-m walkway, while turning direction was self-selected to preserve the pragmatic nature of the standard TUG assessment. Although individual turning strategies may vary, this setup ensured a consistent spatial layout across all participants (Podsiadlo and Richardson, 1991; Thigpen et al., 2000). Each participant performed the test three times, and the average value across the three trials was used for statistical analysis. The use of repeated trials was supported by the high test–retest reproducibility previously reported for the TUG in older adults (Rydwik et al., 2011).

Subphase segmentation and parameter extraction were automatically performed for each trial by the dedicated software. As this was not a validation study of the proprietary algorithm, the analysis focused on the clinically interpretable temporal and kinematic outputs provided by this commercially available system, which included the following parameters:

- Total test duration (s): total time required to complete the iTUG;
- Sit-to-stand duration (s): time taken to rise from the chair to a fully upright standing posture;
- Forward walking duration (s): time taken to walk from the chair to the turning cone;
- Mid-turn duration (s): time required to complete the 180° turn at the cone;
- Return walking duration (s): time taken to walk back from the cone to the chair;
- Final turn duration (s): time required to perform the final 180° turn in front of the chair before sitting down;
- Stand-to-sit duration (s): time taken to return from standing to a fully seated position
- Mid-Turn mean velocity (°/s): average rotational velocity during the mid-turn at the cone;
- Final Turn mean velocity (°/s): average rotational velocity during the final turn before sitting back down.
- Maximum (Max) Flexion/Extension during Sit-to-Stand and Stand-to-Sit (°): peak trunk flexion/extension angle, defined as the maximum angular deviation of the sensor's vertical axis relative to the absolute gravitational vertical within the sagittal plane (Najafi et al., 2002; Roldán-Jiménez et al., 2019).

2.3. Statistical analysis

Statistical analysis was carried out using JASP (version 0.18.3, University of Amsterdam, The Netherlands).

All previously defined parameters were computed for each participant, and an average value across the three trials was calculated for each outcome and used for subsequent analyses. The Shapiro-Wilk test was applied to verify whether the parameters followed a normal distribution. Since the assumption of normality was satisfied, parameters were represented in terms of mean and standard deviation.

A multivariate analysis of variance (MANOVA) was conducted to assess the overall effect of the age group (i.e., independent factor) on the set of dependent variables, represented by the iTUG-derived parameters. The statistical significance level was set at $p < 0.05$ and effect size was evaluated using the eta-squared (η^2). Univariate analysis of variance

(ANOVA) was used as a follow-up test, with the significance level adjusted for multiple comparisons according to the Bonferroni correction. Adjusted *p*-values, as reported by the software, were then considered for significance.

3. Results

A significant main effect of age group was found by the MANOVA on the set of parameters derived from iTUG [$F(39, 581.1) = 2.20$, $p < 0.001$, Wilks'$\lambda = 0.665$, $\eta^2 = 0.13$). The results for all measured parameters are summarized in Table 2**.** Descriptive statistics are reported as mean and standard deviations for each age group. The outcomes of the follow-up one-way ANOVAs and the corresponding post hoc comparisons are also presented within the same table. Fig. 2 provides a visual profile of group differences using radar plots, while Fig. 3 displays the temporal parameters showing a significant age-group effect and at least one significant pairwise post-hoc comparison, highlighting the specific differences between groups. Temporal profiles for all iTUG variables are provided in the Supplementary Materials.

Table 2
Descriptive statistics for all iTUG parameters across the four age groups, together with results from one-way ANOVA and post-hoc comparisons.

Parameter	Group 1 (65–69 years)	Group 2 (70–74 years)	Group 3 (75–79 years)	Group 4 (age ≥ 80 years)	Significant post-hoc comparisons
Total test duration (s)	10.73 ± 1.39	11.39 ± 2.09	12.96 ± 3.31	15.24 ± 6.85 [a, b, c]	Group 4 > Group 1, Group 2, Group 3
Sit-to-Stand duration (s)	1.43 ± 0.26	1.55 ± 0.35	1.62 ± 0.54	1.76 ± 0.71	None
Forward walking duration (s)	2.43 ± 0.51	2.66 ± 0.74	3.26 ± 1.36	4.06 ± 2.93 [a, b]	Group 4 > Group 1, Group 2
Mid-turn duration (s)	2.14 ± 0.33	2.33 ± 0.42	2.53 ± 0.67	2.91 ± 1.06 [a, b]	Group 4 > Group 1, Group 2
Return walking duration (s)	2.19 ± 0.55	2.10 ± 0.64	2.75 ± 1.69	3.19 ± 2.11 [a, b]	Group 4 > Group 1, Group 2
Final turn duration (s)	1.65 ± 0.37	1.85 ± 0.63	2.07 ± 0.76	2.33 ± 0.90 [a, b]	Group 4 > Group 1, Group 2
Stand-to-Sit Duration (s)	0.91 ± 0.33	0.99 ± 0.39	1.23 ± 0.57 [a, b]	1.37 ± 0.56 [a, b]	Group 3, Group 4 > Group1, Group 2
Mid-turn mean velocity (°/s)	83.18 ± 9.79	76.35 ± 11.72	70.68 ± 14.09 [a]	62.71 ± 15.66 [a, b, c]	Group 3 < Group 1 Group 4 < Group 1, Group 2, Group 3
Final turn mean velocity (°/s)	103.42 ± 20.42	95.12 ± 23.92	87.37 ± 23.07 [a]	76.00 ± 22.69 [a, b]	Group 3 < Group 1 Group 4 < Group 1, Group 2
Max Flexion during Sit-to-Stand (°)	40.12 ± 12.49	37.86 ± 10.17	42.26 ± 12.43	43.35 ± 10.44	None
Max Extension during Sit-to-Stand (°)	15.24 ± 12.38	12.71 ± 8.52	17.87 ± 10.89	18.66 ± 12.10	None
Max Flexion during Stand-to-Sit (°)	21.11 ± 21.47	17.05 ± 20.16	26.96 ± 21.63	30.22 ± 24.86	None
Max Extension during Stand-to-sit (°)	6.60 ± 5.58	4.91 ± 3.80	5.77 ± 4.52	7.21 ± 6.21	None

Superscript letters indicate statistically significant post-hoc differences: a, significantly different from Group 1; b, significantly different from Group 2; and c, significantly different from Group 3. The final column reports all statistically significant Bonferroni-adjusted pairwise comparisons, allowing identification of the age strata in which differences were observed.

Overall, age-group differences were not uniform across all iTUG parameters. The most evident differences were observed in participants aged ≥80 years, particularly as regards total test duration, walking and turning durations, and turning angular velocities. In particular, total test duration was significantly longer in those aged ≥80 than in all younger participants, who also exhibited significanlty increased duration of forward walking, mid-turn, return walking, and final-turn with respect to participants of both Groups 1 and 2. Some differences were already detectable in participants aged 75–79 years: stand-to-sit duration was significantly longer in Groups 3 and 4 than in Groups 1 and 2, while mid-turn and final-turn mean velocities were significantly lower in Group 3 than in Group 1. Thus, even though it was not possible to identify a common threshold age across all outcomes, the most consistent age-stratified differences emerged from 80 years onward.

The duration of walking and turning phases were found generally longer among those belonging to the older age groups. Forward walking duration increased from 2.43 ± 0.51 s in Group 1 to 4.06 ± 2.93 s in Group 4, mid-turn duration from 2.14 ± 0.33 s to 2.91 ± 1.06 s, return walking duration from 2.19 ± 0.55 s to 3.19 ± 2.11 s, and final-turn duration from 1.65 ± 0.37 s to 2.33 ± 0.90 s. Post-hoc comparisons showed that, for all four parameters, Group 4 systematically reported significantly longer durations than Groups 1 and 2.

Total test duration followed a similar pattern, increasing from 10.73 ± 1.39 s in Group 1 to 15.24 ± 6.85 s in Group 4. Group 4 showed a significantly longer total duration than all the younger groups. With respect to postural transitions, stand-to-sit duration increased from 0.91 ± 0.33 s in Group 1 to 1.37 ± 0.56 s in Group 4, with significantly longer durations in Groups 3 and 4 than in Groups 1 and 2. Conversely, sit-to-stand duration increased from 1.43 ± 0.26 s to 1.76 ± 0.71 s, but no statistically significant differences were observed across groups.

In addition, turning velocities were reduced in the older age groups. In particular, mid-turn mean velocity decreased from 83.18 ± 9.79°/s in Group 1 to 62.71 ± 15.66°/s in Group 4. Post-hoc comparisons showed that mid-turn mean velocity was significantly lower in Group 3 than in Group 1 and in Group 4 than in Groups 1, 2, and 3. Similarly, final-turn mean velocity decreased from 103.42 ± 20.42°/s in Group 1 to 76.00 ± 22.69°/s in Group 4. Final-turn mean velocity was significantly lower in Group 3 than in Group 1 and in Group 4 than in Groups 1 and 2.

Regarding trunk kinematics, no significant differences were observed in maximum trunk flexion or extension during either the sit-to-stand or the stand-to-sit transitions. Although mean values tended to be higher in the oldest participants, the differences did not reach statistical significance. Within the present sample, trunk angular measures showed less pronounced age-stratified differences compared to temporal and velocity-based iTUG parameters.

4. Discussion

The main purpose of the present study was to characterize age-stratified differences in functional mobility using iTUG-derived parameters in community-dwelling older adults. Specifically, the study aimed to identify which iTUG subtasks and parameters showed the most pronounced differences across age strata and to describe phase-specific temporal and kinematic features from 65 years onward using a pragmatic single-sensor approach. Overall, the results showed significant differences across age groups, mainly involving total test duration, walking and turning durations, and turning velocity. These findings suggest that temporal and velocity-based parameters, particularly those related to walking and turning phases, were more sensitive to age-stratified differences than trunk angular measures during postural transitions.

It is noteworthy that differences in iTUG performance were not

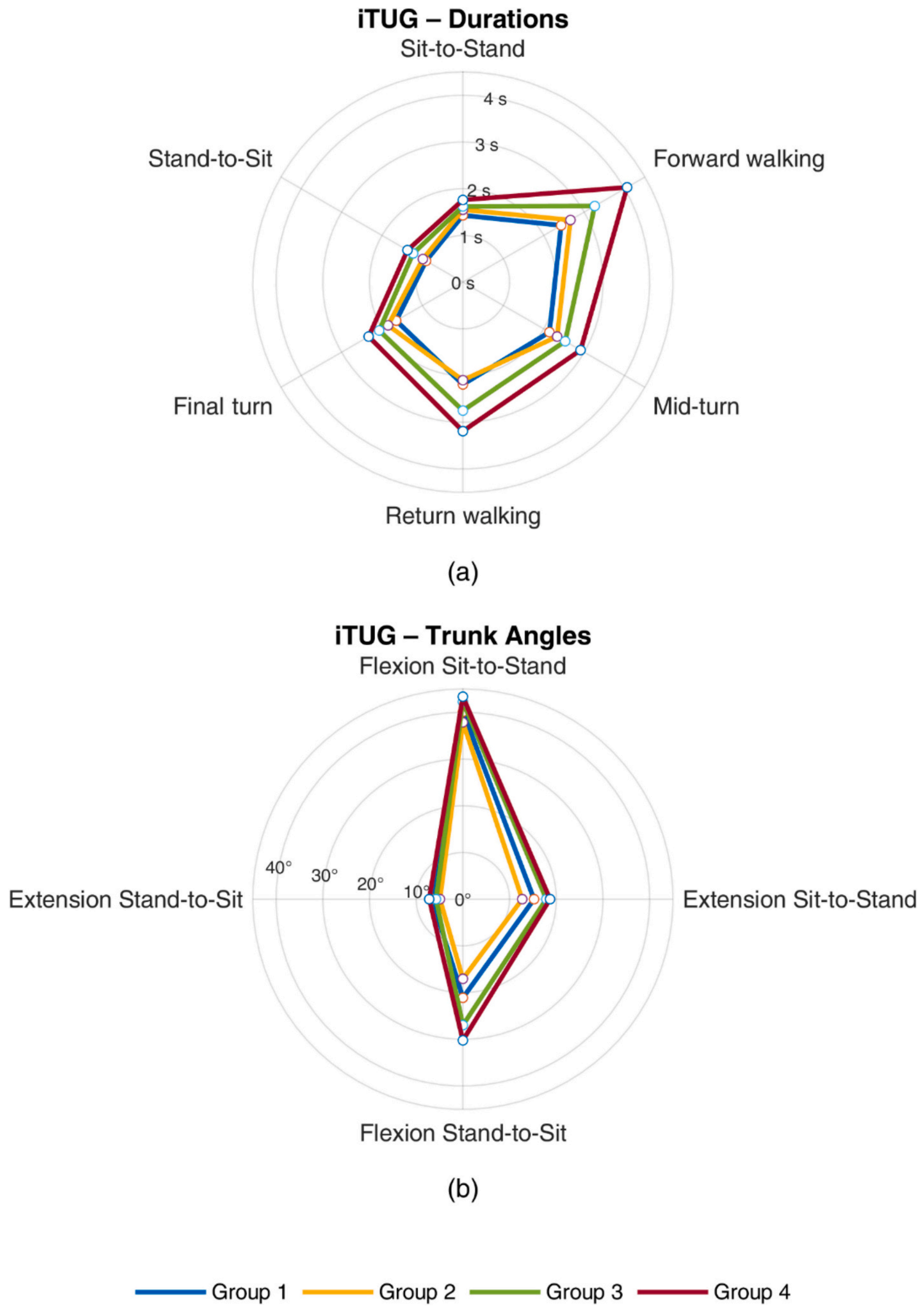

Fig. 2. Radar plots of iTUG subcomponents. (a) Duration parameters, including forward walking, return walking, mid-turn and final-turn durations, sit-to-stand, and stand-to-sit. (b) Trunk kinematics, showing maximum flexion and extension during sit-to-stand and stand-to-sit. Each polygon represents the average performance of one age group. Larger values correspond to slower transitions or greater angular displacement.

evenly distributed across the four age groups. Indeed, the most evident differences in terms of total test duration and most walking- and turning-phase durations, involved those aged ≥80 years, while participants of groups aged 65–69 and 70–74 years generally showed comparable performance. However, differences in stand-to-sit duration and turning velocity were already present in the 75–79-year group. Taken together, such findings suggest that measurable differences in some components of functional mobility may become more pronounced during the late seventies and especially from 80 years onward, rather than changing uniformly across consecutive five-year age intervals. However, because of the cross-sectional design, unequal group composition, and the absence of formal nonlinear modelling, these findings should not be interpreted as evidence of a definitive age threshold or a nonlinear aging trajectory.

Importantly, the age-stratified differences observed in total iTUG duration were broadly consistent with previously reported values for the traditional TUG test in comparable populations [41]. This agreement supports the plausibility of the present findings and indicates that instrumented assessment can capture comparable patterns while providing additional phase-specific information beyond total completion time alone.

With respect to walking phases, both forward and return walking durations were significantly longer in older age groups, particularly in participants aged 80 years and over. These findings are consistent with previous evidence showing that walking speed is an important indicator of mobility performance in older adults (Graham et al., 2010; Studenski et al., 2011). Although longer walking durations may be compatible with age-related changes potentially reflecting the effects of age-related

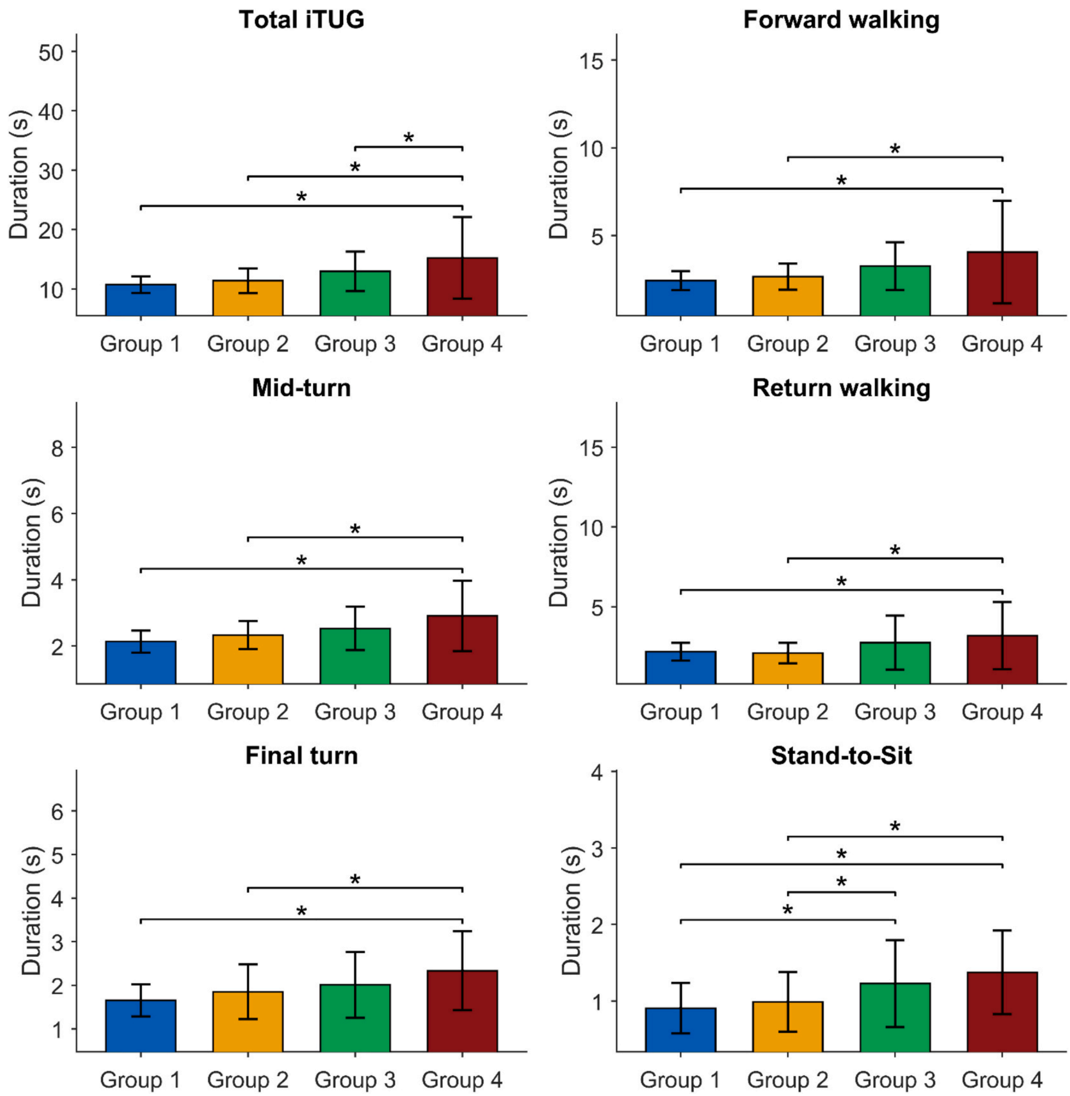

Fig. 3. Age-group differences in selected temporal parameters derived from the instrumented Timed Up and Go test (iTUG). Bars represent group means, while error bars indicate standard deviations. Only temporal variables showing a significant age-group effect in the follow-up one-way ANOVAs and at least one significant between-group post-hoc comparison are displayed. Horizontal brackets identify the specific pairwise comparisons, and the asterisk indicates a statistically significant difference between the connected groups ($p < 0.05$).

joint stiffness, reduced stride length and longer stance phases, due to reduced muscle strength, balance, and slower neuromuscular response (Prince et al., 1997; Boyer et al., 2023) the present study did not include direct measures of muscle strength, stride length, joint stiffness, or neuromuscular function. Therefore, such mechanistic interpretations should be considered cautious and hypothesis-generating.

Turning-related parameters also showed clear age-stratified differences. Turn durations were significantly longer in participants aged ≥80 years than in Groups 1 and 2, whereas reductions in mean turning velocity were already detectable in the 75–79-year group compared with the youngest group. These findings suggest that turning velocity may identify age-related differences earlier than turning duration within the age strata considered. This finding is relevant because turning represents a demanding component of functional mobility and has been associated in previous studies with balance performance and fall risk (Roldán-Jiménez et al., 2019; Bohannon, 2006).

Postural transition parameters showed a more heterogeneous pattern, suggesting that not all iTUG subtasks are equally sensitive to age-stratified differences in this sample. In particular, stand-to-sit duration increased significantly across age-groups, which may reflect diminished eccentric control, joint stiffness and a shift toward slower, more cautious movement strategies (Muir et al., 2010; Shukla et al., 2020; Janssen et al., 2002). Conversely, sit-to-stand duration remained relatively stable, with no significant differences across the age groups. This result does not follow the expected age-related trend, as the task mainly depends on lower-limb extensor strength, which typically decreases with age (Porta et al., 2018). The absence of significant age-group differences in sit-to-stand duration may partly reflect unmeasured heterogeneity in lower-limb strength, habitual physical activity, and functional status across participants and recruitment sources.

Overall, the subphase-level analysis suggests that the differences in total iTUG duration were not uniformly distributed across all components of the test. Rather, walking and turning phases appeared to contribute more clearly to the age-stratified differences observed in global performance. This represents a relevant contribution of the instrumented approach, as total TUG duration alone does not indicate which specific mobility components account for between-group differences. Therefore, the present findings support the value of subtask-level iTUG analysis for characterizing functional mobility in older adults, while confirming that further studies are needed to determine the clinical and prognostic relevance of these parameters.

In contrast to the temporal and velocity parameters, maximum trunk flexion and extension angles during sit-to-stand and stand-to-sit transitions did not show significant differences across age groups. Although some variability was observed, these findings suggest that trunk angular measurements are less sensitive to age-stratified differences than walking and turning-related parameters in the present sample. Previous literature has reported mixed findings regarding trunk kinematics during postural transition in older adults, with possible differences in movement strategies across individuals. Some studies report that older adults adopt more constrained trunk movements during descent, possibly as a strategy to enhance postural stability (Jeon et al., 2021; Dubost et al., 2005). Conversely, other evidence indicates that when lower-limb strength is reduced, older adults may rely on greater trunk flexion or extension as a compensatory strategy to complete the transition (Van Lummel et al., 2018). Taken together, these findings suggest that trunk angular displacement may be less sensitive to aging than other mobility parameters, with inter-individual differences reflecting diverse compensatory strategies rather than a uniform change.

In summary, our findings suggest that age-related differences in functional mobility are not uniformly distributed across either iTUG subtasks or consecutive age strata. The most consistent differences were observed in participants aged ≥80 years, while selected alterations in turning velocity and stand-to-sit duration were already evident in the 75–79-year group. From a clinical perspective, the iTUG test provides detailed, quantitative insights into specific subcomponents of mobility (e.g., turning, transition phases, gait speed), beyond a single total duration. This objective breakdown may facilitate the detection of phase-specific alterations that are potentially linked to functional decline. Ultimately, incorporating iTUG into routine assessments could provide a more comprehensive functional profile to help inform targeted interventions.

However, several limitations should be acknowledged. First, the retrospective cross-sectional design prevents conclusions about longitudinal changes within individuals, and the observed differences may partly reflect cohort effects rather than true aging processes. Second, the adopted age stratification (Buehler et al., 2024) led to a smaller sample size in Group 1, and greater inter-individual variability in the oldest group, which may have influenced the precision and stability of some estimates. Third, although eligibility criteria were used to exclude major conditions expected to severely affect mobility, several potentially relevant individual and contextual factors, such as socio-economic status, educational level, living environment, habitual physical activity, and the presence of comorbidities, were not systematically collected or included as covariates in the present analysis. Furthermore, the unequal sex distribution across groups prevented a reliable sex-stratified analysis. Therefore, the potential influence of these factors on the observed group differences cannot be excluded and should be investigated in future studies. Furthermore, the unequal sex distribution across groups prevented a reliable sex-stratified analysis. Although previous findings suggest that age affects iTUG performance more heavily than sex (Porta et al., 2018), the potential influence of this unbalanced distribution on our results cannot be completely ruled out. Therefore, all these factors should be considered in future studies. Finally, subphase segmentation and parameter extraction were performed using a commercially available software according to the manufacturer's iTUG protocol. Since the present study was not designed as a validation study of the proprietary algorithm, the accuracy of the segmentation procedure was not directly assessed in this dataset.

In conclusion, the present study provides descriptive age-stratified data on phase-specific iTUG parameters in community-dwelling older adults. Temporal and velocity-based measures, especially those related to walking and turning, showed clearer differences across age groups than trunk angular measures during postural transitions. The most consistent differences were concentrated in participants aged ≥80 years, although selected turning-velocity and stand-to-sit measures already differed in the 75–79-year group. This pattern indicates that age-related differences in iTUG performance were not uniformly distributed across consecutive five-year age strata. These findings support the usefulness of a pragmatic single-sensor iTUG approach for characterizing which components of functional mobility differ across older age strata. However, the results should not be interpreted as evidence of longitudinal functional decline or as normative reference thresholds. Despite these limitations, the integration of temporal, kinematic, and trunk-derived metrics in future longitudinal research may help clarify how mobility impairments evolve over time and identify which parameters are most responsive to targeted interventions in older adults.

CRediT authorship contribution statement

Serena Cerfoglio: Writing – original draft, Software, Methodology, Formal analysis, Data curation, Conceptualization. **Massimiliano Pau:** Writing – original draft, Supervision, Resources, Methodology, Formal analysis, Conceptualization. **Giuseppina Bernardelli:** Writing – review & editing, Resources. **Micaela Porta:** Writing – review & editing, Visualization, Investigation. **Giulia Casu:** Writing – review & editing, Visualization, Investigation. **Manuela Galli:** Writing – review & editing, Supervision, Funding acquisition. **Veronica Cimolin:** Writing – original draft, Supervision, Resources, Methodology, Conceptualization.

Informed consent

Written informed consent was obtained from all participants included in this study.

Ethical approval

This study was approved by Ethical committees of the University of Milan (authorization number 12_2019) and ATS Sardegna, Italy (authorization number 300/2021/CE).

Funding

The study was supported by the MUSA—Multilayered Urban Sustainability Action— project funded by the European Union's NextGenerationEU under the National Recovery and Resilience Plan (NRRP) Mission 4, Component 2, Investment Line 1.5: Strengthening of Research Structures and Creation of R&D “Innovation Ecosystems” of “territorial leaders in R&D".

Declaration of competing interest

The authors have no competing interests to declare that are relevant to the content of this article.

Acknowledgements

Authors would like to thank Niccolò Faggiani, Giulia Beaufils, Jacopo Finotti and Rihem Khelifi for their help in data sorting and analysis.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jelekin.2026.103198.

Data availability

Data are available from the corresponding author upon reasonable request.

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