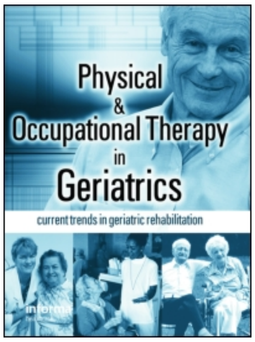

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Monitorization of Timed Up and Go Phases in Elderly

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ABSTRACT

Aims: to characterize functional mobility during timed "Up and Go" (TUG) test using Wiva® science sensor and to identify which parameter of TUG test best correlates with health-related outcomes in elderly.

Methods: 1598 participants (71.53 ± 4.99 y, 64.1% women) were recruited. The body mass index (BMI), muscle strength, health status, and all TUG phases (sit-to-stand, gait-to-go, turning, gait-return, and stand-to-sit) were evaluated. 5-TUG performance-group scores are reported for the <20th; 20–40th, 40–60th, 60–80th, 80–100th percentiles, as there is no health standard cutoff for Portuguese elderly. The Pearson's correlations were assessed between variables ($p < 0.05$).

Results: The best TUG performers (<20th) presented better results than the other groups for all tests, with the exception of the Turning phase. Both gait, sit-to-stand and stand-to-sit were inversely correlated with health status and muscle strength, and positively correlated with BMI.

Conclusions: All phases of TUG test are an important tool to assess functional mobility, providing complementary data for clinical settings in elderly population.

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KEYWORDS
Active aging; functional mobility; quality of life; timed up and go; inertial sensor

Introduction

The aging process has been associated with neuromuscular alterations that may cause a decreased muscle strength and power generation and ultimately lead to a progressive decline of the ability to perform activities of daily living and loss of independence.[1–4] In an attempt to identify people at risk of negative health-related outcomes and to assess the effectiveness of therapeutic interventions, several tools have been developed to objectively measure physical function and mobility in older adults. One of the most used explore an extensive protocol to assess muscle strength, resistance, flexibility, velocity and agility, including the timed "Up and Go" (TUG)

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test.[5,6] The TUG test has been shown to be a reliable, inexpensive, and easy tool, validated in several specific populations, such as elderly.[7] Moreover, TUG test[8,9] was also able to evaluate proactive balance, i.e., anticipating a predicted disturbance such as crossing or walking around an obstacle.[10,11] Several studies demonstrated that TUG test provides useful outcomes related with falls risks.[8,9] Data from previous studies showed that TUG test aims to assess agility,[12,13] balance,[11,14] functional mobility[15] and lower extremity functioning[9], such as, knee extension strength,[15] gait speed and endurance,[7] as well as some cognitive domains (e.g., executive function) in older adults, indicating that this test predict health decline and disability in the activities of daily living in older adults[9,11] and may be useful as a clinical tool to evaluate basic mobility skills.

Recently, new wireless instrumentation was validated[16] and introduced[13] for motion analysis, allowing assessment of patients' functional status and implement the most effective therapeutic strategy, such as Wiva® science sensor.[17,18] The use of Wiva® science sensor gives additional and more reliable parameters to assess gait, balance and agility, including duration of five different phases: sit-to-stand, gait-to-go, turning, gait-return, and stand-to-sit duration.[17,18] Despite the interesting results from these studies, no studies have established whether or not these additional parameters (TUG phases) are correlated between them or have different impact on TUG final score. Therefore, we aimed at characterizing functional mobility during TUG test performance using Wiva® science sensor and then to identify which parameter of TUG test best correlates with muscle strength and health status in community-dwelling older adults.

Materials and methods

Study design

This is a cohort study, based on the first-year assessment of older healthy adults who were participating in a two-year prospective study designed to assess the functional and physical capacity. All subjects were part of a regular physical exercise program funded and organized by community members of a city in north Portugal. Recruitment occurred via advertisement and word of mouth and written informed consent was obtained from each participant. The study was approved by the local Institutional Review Board and was conducted in accordance with the provisions of the Declaration of Helsinki.

Participants

A total of 1598 community-dwelling (1025 women and 573 men) aged 65 or older (for detail, see Table 1) from the 3161 registered on the local

Table 1. Anthropometric variables and TUG test scores by performance groups.

	Total sample ($n = 1598$)	Group 1 ($n = 323$)	Group 2 ($n = 318$)	Group 3 ($n = 318$)	Group 4 ($n = 320$)	Group 5 ($n = 319$)
Percentile	–	<20th	≥20th, <40th	≥40th, < 60th	≥60th, <80th	≥80th
Interval time TUG (s)	[4.26, 23.02]	[4.26, 6.42]	[6.43, 7.26]	[7.27, 8.12]	[8.13, 9.35]	[9.36, 23.02]
Age (years)	71.53 (4.99)	69.81 (3.76)$^{3–5}$	70.30 (4.16)^{4,5}	71.06 (4.72)^{1,5}	72.17 (4.89)^{1,2,5}	74.36 (5.85)$^{1–4}$
Female (%)	64.1%	45.8%	59.7%	62.6%	72.8%	79.9%
Height (cm)	156.49 (8.12)	159.27 (8.21)$^{3–5}$	157.82 (8.11)^{4,5}	156.56(7.88)^{1,5}	154.90(7.82)^{1,2}	153.87(7.40)$^{1–3}$
Weight (kg)	72.75 (11.61)	71.09 (11.49)^{5}	71.88 (11.81)	73.20(11.22)	73.27(11.35)	74.32(11.94)^{1}
BMI (kg/m^2)	29.70 (4.25)	27.94 (3.63)$^{3–5}$	28.78 (3.68)$^{3–5}$	29.92 (4.43)^{1,2,5}	30.49 (4.20)^{1,2}	31.38(4.39)$^{1–3}$
TUG						
Sit-to-stand (s)	1.40 (0.46)	1.12 (0.28)$^{2–5}$	1.24 (0.31)^{1,4,5}	1.32 (0.30)^{1,4,5}	1.45 (0.37)^{1,2,3,5}	1.86 (0.60)$^{1–4}$
Gait-to-go (s)	2.03 (0.66)	1.54 (0.42)$^{2–5}$	1.79 (0.40)$^{1–5}$	1.93 (0.41)^{1,2,4,5}	2.15 (0.38)^{1,2,3,5}	2.76 (0.86)$^{1–4}$
Turning (s)	1.11 (0.48)	0.98 (0.39)^{4,5}	0.98 (0.45)^{4,5}	1.07 (0.43)^{5}	1.11(0.45)^{1,2,5}	1.40 (0.56)$^{1–4}$
Gait return (s)	1.86 (0.57)	1.36 (0.36)$^{2,3–5}$	1.64 (0.36)$^{1,3–5}$	1.81 (0.37)^{1,2,4,5}	1.99 (0.38)^{1,2,3,5}	2.50 (0.64)$^{1–4}$
Stand-to-sit (s)	1.60 (2.06)	0.74 (0.38)$^{2–5}$	1.21 (0.46)$^{1,3–5}$	1.58 (0.47)^{1,2,4,5}	1.92 (0.55)^{1,2,3,5}	2.69 (0.85)$^{1–4}$
Total time (s)	8.02 (2.10)	5.73 (0.49)$^{2–5}$	6.86 (0.24)$^{1,3–5}$	7.70 (0.25)^{1,2,4,5}	8.63 (0.34)^{1,2,3,5}	11.22 (2.09)$^{1–4}$
Strength lower limbs						
Sit-to-stand (reps)	13.04 (3.47)	15.03 (4.09)$^{2–5}$	13.58 (3.13)^{1,4,5}	13.03 (3.71)^{1,5}	12.38 (3.04)^{1,2,5}	11.02 (2.91)$^{1–4}$
Health status						
EQ-5D-5L index	0.83 (0.18)	0.90 (0.12)^{3,4,5}	0.87 (0.15)^{1,4,5}	0.84 (0.17)^{1,5}	0.81 (0.18)^{1,2,5}	0.73 (0.22)$^{1–4}$

Data as expressed by mean (SD). BMI, body mass index; TUG, timed up and go; EQ-5D-5L, health questionnaire; reps, repetitions.
Superscript numbers represent the TUG groups (1–5) that are significantly different ($p < 0.05$) from the one showed.

program were recruited to participate in the present study. Participants had the option for building their own physical exercise program according to self-motivation and schedules. The inclusion criteria used in the present study were: (a) being 65 years of age and older and (b) to have physical, motor and psychic independence. The exclusion criteria were: (a) presence of prostheses or use of locomotion aids, (b) having a neurological or orthopedic pathology, or (c) recent injury in the lower or upper limbs. All participants completed socio-demographic information and health status questionnaires.

Physical and health-related quality of life assessments

Anthropometric measures

An excessive body mass index (BMI) has been associated with dynamic balance impairments, which can contribute to a reduced ability to perform daily activities.[17,19] Height and weight were measured respectively to the nearest 0.1 cm using a stadiometer (SECA 217, Germany) and to the nearest 0.5 kg using the Tanita BC-545 Body Composition Analyzer (Tanita, Inc., Tokyo, Japan). Subjects were asked to dress light clothing and stood barefoot, with eyes directed straight ahead according to the standards procedures of the International Society for the Advancement of Kinanthropometry.[20] Body mass index was calculated as weight (kg) divided by height (m) squared.

Lower limbs muscle strength. The 30 s – chair stand test (30 s-CS) was used to assess lower limbs muscle strength during sit-to-stand and stand-to-sit transitions as lower limb strength has been related to the most demanding activities of daily life.[4,21] Participants have to perform the maximum of full stands that can be completed in 30 s with arms folded across the chest, as previously described by Rikli and Jones.[22] After demonstration by the tester, a practice trial of one to three repetitions was given, followed by a single 30-second test trial. The total number of stands executed correctly was recorded.[5]

Timed-up and go (TUG) test

The TUG test was used to assess the agility, mobility and balance. Participants were required to perform TUG test followed a verbal instruction to stand up from an armless chair with (46 cm height), walk 3 m as fast as possible, turn around a cone placement, walk back, and sit down again.[23] The test was assessed with Wiva® science sensor (Loran Engineering, Bologna, Italy), a set of wireless inertial detection devices placed at the level of the participants L4–L5 spinal segment. Wiva® science sensors include an accelerometer, a magnetometer and a gyroscope that allows professionals to gather information about the angular velocities reached during TUG test. In addition, Wiva® records the duration of each of the 5 TUG phases as follows: (i) sit-to-stand, (ii) gait-to-go, (iii) turning, (iv) gait-return, and (v) stand-to-sit. The total time required to complete the test was also monitored. All this information were saved in a PC via Bluetooth with Biomech Study 2011 v.1.1.[17] After the criterion trial to become familiar to the test, each participant performed a single trial.

According to results of the whole sample, participants were divided into five groups based on TUG test performance percentiles: <20th; 20–40th, 40–60th, 60–80th, and 80–100th as there is no standard cutoff for health Portuguese older adults.

Health status

The EQ-5D questionnaire is a generic instrument for describing and measuring individual Health value,[24] that has been shown to emphasize the relative impact of musculoskeletal disorders in older adults.[25] It consists of two parts, a descriptive system and a visual analogue scale (EQ-VAS). The descriptive system measures five health dimensions (mobility, self-care, usual activities, pain/discomfort and anxiety/depression) with five levels of severity each: no problems, slight problems, moderate problems, severe problems, and unable to/extreme problems.[26] The health status is converted to a single summary index (EQ-5 D index) by applying a formula that sets up weights to each of the levels in each dimension.[27] The formula is based on the valuation of EQ-5D health status obtained from general population sample using the standardized extended version of the EQ-5D, being that utility scores are bounded from −0.281 to 1.[24] Additionally, the visual analogue scale EQ-VAS is used to rate respondent's current self-rated health on a 20 cm visual analogue scale ranging from 0 (worst imaginable health) to 100 (best imaginable health).[26,28]

Statistical analysis

The sample was divided in groups using the TUG cutoff values of 20th, 40th, 60th, and 80th percentiles, resulting in five performance groups with equal number of participants. Group 1 was constituted by the best performers, and group 5 by the slowest performers in TUG test. Descriptive statistical analysis (mean ± standard deviation) was used for the characterization of the participants. The statistical differences between groups were performed using an analysis of variance (ANOVA) followed by the Bonferroni multiple comparisons post hoc tests. The Pearson's correlation coefficient (r) was calculated to understand the strength of relationship between variables. All statistical analyses were performed using SPSS statistics (version 22; SPSS, Inc., Chicago, IL) for Windows with a significance level of 0.05.

Results

Characteristics of the total sample are presented in Table 1. From the total of 1598 participants, 64.1% were females. The average age for the total sample was 71.53 ± 4.99 years, and the BMI values were 29.70 ± 4.25. In relation to the average values of BMI, groups 1, 2, and 3 were classified as overweight (25.0–29.9 kg/m^2) and the groups 4 and 5 as obese ($\geq$30 kg/m^2). Data stratification of TUG total performance time ranged from 4.26 to 23.02 s. Lower limb strength mean repetitions were 13.04 ± 3.46, while health status index average was 0.83 ± 0.18.

Looking for the age and sex of the different TUG groups, a significant effect of these two personal characteristics in the TUG performance can be seen, with group 1 being younger (69.8 ± 3.76 years) and mostly constituted by men (54%), while group 5 was the oldest group (74.36 ± 5.85 years), mostly women (80%). Regarding the TUG parameters, lower limb strength and health status index, a trend for a detriment in performance from group 1 to group 5 can be observed. Post hoc tests between groups show that best TUG performers (Group 1) presented significantly better results than the other groups for all tests, with the exception of the Turning phase, where no differences were found between group 1 and groups 2 and 3. Worst TUG performers (Group 5) showed worst statistically significant results for all tests.

In Figure 1 we show the average values for health status index, BMI and lower limb muscle strength according to the TUG performance, separated by sex. In both sex groups (Figure 1A), the shape of health status curves decreases from group 1 to group 5. A lower value was observed in all female groups, being evident a faster decline in group 5. In fact, it was observed a decrease of 19.5% in female and 9.8% in male groups. Both gender groups presented a decrease in lower limb muscle strength from group 1 to group 5 (Figure 1B). The percent of decline observed in the 30 s-chair stand, was 26.1% for male and 24.3% for female groups. Both male and female participants showed an increase in BMI from group 1 to group 5 (Figure 1C). In male groups prevailed the overweight category with an increase of 8.6% in BMI, and in female groups the obese category with an increase of 11.6%.

The correlation between TUG and TUG partial scores and health-related outcomes is presented in Table 2. Generally, total time of TUG test was inversely associated with lower limb strength and health status ($r = -0.367$, $r = -0.350$, $p \leq 0.001$; respectively) and positively associated with BMI ($r = 0.335$, $p < 0.001$). Both, gait-to-go and gait-return phases, were

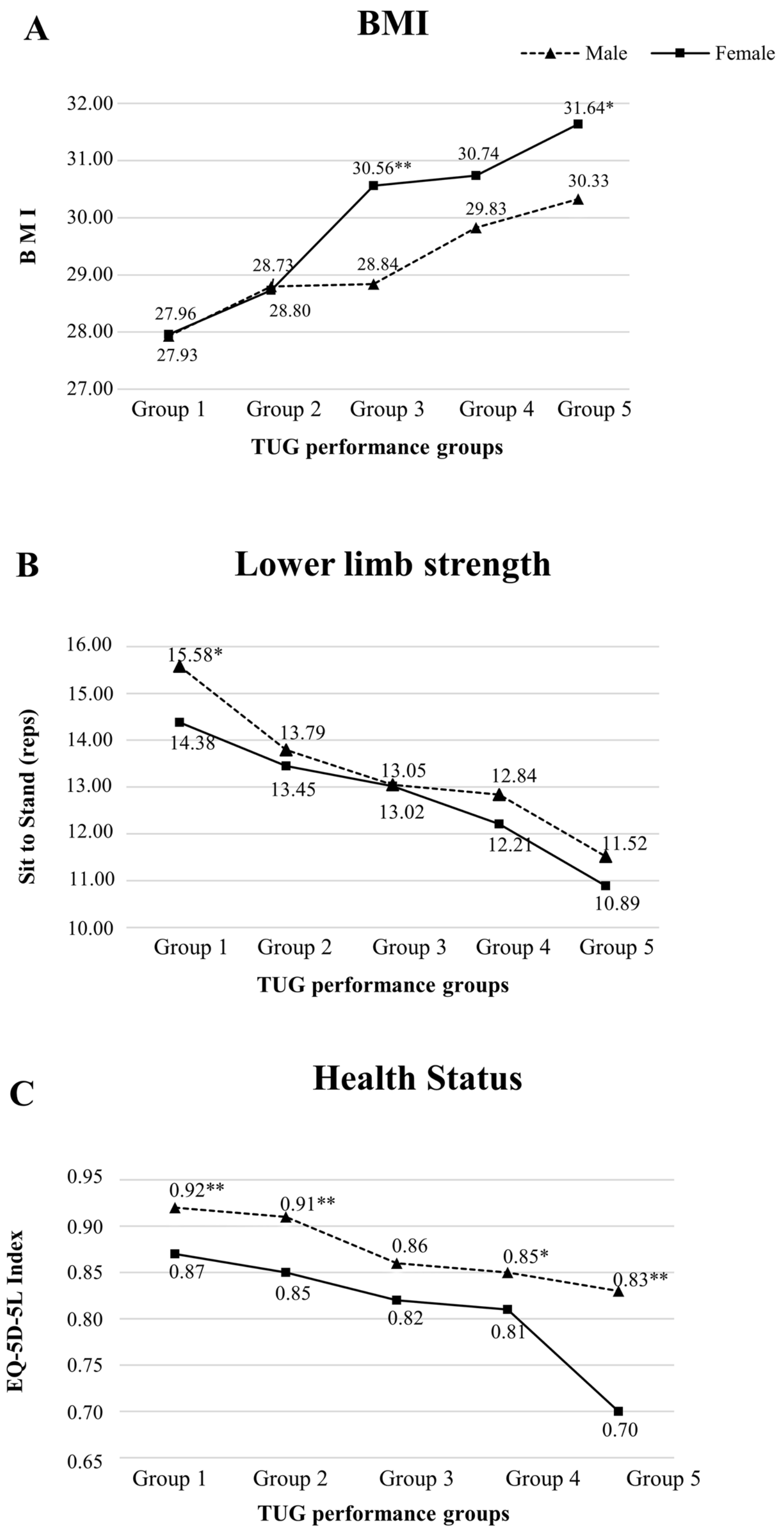

Figure 1. Mean values stratified by gender and TUG performance groups in (A) BMI, (B) lower limbs strength, and (C) Health status. Significant differences between genders $*p < 0.05$; $**p < 0.001$.

Table 2. Correlation (controlling for age) between TUG test performance with lower limb muscle strength, health status index, and BMI.

TUG	BMI	30 s-CS	Health status
Total time	0.335**	−0.367**	−0.350**
Sit-to-stand	0.195*	−0.192*	−0.225**
Gait-to-go	0.195	−0.297**	−0.282**
Turning	0.206**	−0.099	−0.097**
Gait-return	0.225	−0.325**	−0.270
Stand-to-sit	0.251	−0.247	−0.241**

*$p < 0.05$; **$p \leq 0.001$.

inversely correlated with muscle strength ($r = -0.297$, $r = -0.325$, $p \leq 0.001$) respectively, and health status ($r = -0.282$, $p \leq 0.001$) was inversely correlated with gait-to-go phase. An inverse correlation between sit-to-stand phase, muscle strength ($r = -0.192$, $p < 0.05$), and health status ($r = -0.225$, $p \leq 0.001$), and between stand-to-sit and health status ($r = -0.241$, $p \leq 0.001$) was found. Furthermore, BMI was positively correlated with sit-to-stand ($r = 0.195$, $p < 0.05$) and turning ($r = 0.206$, $p \leq 0.001$) phases.

Discussion

The main findings of the present study demonstrate that the monitorization of all TUG phases provides a range of quantitative measures related to health status and muscle strength, in active older adults. Moreover, muscle strength was associated with both gait phases, and both sit-to-stand and stand-to-sit phases were associated with health status.

The ability to get up and sit on a chair is considered one of the most mechanically demanding physical activities in daily life.[19,29] The correlation observed between both sit-to-stand and stand-to-sit phases and health status is consistent with previous studies.[29] As the ability to stand up and sit requires a significant leg muscle strength, a wide range of joint movement, and good balance control[30,31] our findings point out functional mobility as a crucial ability for independence and quality of life in older adults. Previous research has shown that older adults that included the sit-to-stand activity as part of their daily care routines (e.g. during dressing or toileting), demonstrated less decline in mobility and functional outcomes.[30] However, Weiss et al[32] observed that both sit-to-stand and the stand-to-sit phases duration were not significantly different between fallers and non-fallers, but draw to a close that fallers have difficulty with specific TUG aspects that may be quantified using an accelerometer.[32] Therefore, the instrumented version of TUG could be a more useful test of balance and mobility in higher functioning groups, as more details of the quality and quantity of the performance can be obtained.[11,33]

An inverse correlation between lower limb muscle strength and TUG performance has been reported.[4] Our results confirm that TUG partial scores (gait-to-go and gait-to-return) can also be useful to predict muscle weakness. In fact, gait speed has been associated to prediction in most of geriatric outcomes, including a higher probability of incident activities of daily living disability and functional limitations[34], as TUG does.[32,35] Our data are in line with previous studies[36] and the scores of the lower limbs strength measured with the 30 s-CS are consistent with the normative values reported for Portuguese older adults.[37] This is important as the age-related decline in lower limb strength (35.5% in female and 31.1% in male) of Portuguese older adults has a faster rate than those from other countries.[37] Interestingly, in the present study, a lower age-related decline in lower limbs strength (24.3% and 26.1%, female and male, respectively) was found and a substantially higher rate of physically active older adults compared to other studies,[37]. Such evidence may, partially, explain our findings as the benefits of exercising on leg strength in older adults has been reported.[10,15] Although our results may help to establish the association between the TUG partial scores and the lower limbs muscle strength, further research on the effectiveness of TUG phases in predicting this assumption is needed.

Aging induces several body changes, including increases in body weight, body fat and fat distribution, which may affect physical and mental health.[38] The association between BMI and physical function measured as TUG test has been reported previously.[17,19] Present findings also show the positive association between TUG partial scores and BMI, being better correlated with the Turning phase. In previous studies, authors reported that obese patients performed turns slower than their lean counterparts,[19] with the underlying reason, that an increased mechanical constraint due to extra weight, could translate in balance control impairments and more difficulty to accomplish the turn.[17,19] Furthermore, gender differences in the TUG test have been demonstrated in the literature, with male generally performed better than female.[37] Despite gender differences, older adults who take 12 s or more to complete the TUG test are considered at high risk of falling.[39] Our sample is identified with the overweight category with a mean TUG performance of 8.02 s, demonstrating scores below the risk factor. Although it is challenging to distinguish the direction of the association between BMI and balance parameters in older adults, higher levels of physical activity are frequently indicative of better balance,[17] suggesting that the participants in the present study may have benefited from a regular physical activity performed at least twice a week.

Conclusions

Our findings indicate that TUG phases are correlated with health status and lower limb muscle strength. This is particularly evident on Gait-return and Gait-to-go TUG phases. The higher scores on TUG test, meaning less time to perform it, the best the health status. Despite being significant different, men and women present similar behavior. Both show an age-related decline on muscle strength and increases on BMI. Confirming literature reports, the age and muscle strength has an important impact on health status. The present findings provide a complementary data information for clinical intervention in elderly population.

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