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Normative values of functional reach test, single-leg stance test, and timed "UP and GO" with and without dual-task in healthy Iranian adults: A cross-sectional study

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ABSTRACT

Background: Balance impairment is a common problem in all age groups. There are several tools to assess balance. Functional reach test (FRT), single-leg stance (SLS) test, timed up and go (TUG) test, and TUG with the cognitive dual-task (TUGcog) are commonly employed balance tests. The current study aimed to determine the normative values of FRT, SLST, TUG, and TUGcog across age groups and genders in healthy Iranian adults.
Methods: We designed a cross-sectional study, and 240 healthy adults (120 males and 120 females) in six age groups (18–29, 30–39, 40–49, 50–59, 60–69, ≥70 years) completed FRT, SLST, TUG, and TUGcog based on the Persian version of BESTest instructions.
Results: There were significant age-specific declines in balance performances. Gender had effects on 18–29 years and older adults (≥60 years), and males performed better than females. Male and females had similar performance on the TUG and TUGcog tests in 60–69 years ($p > 0.05$).
Conclusions: The normative values of FRT, SLS, TUG, and TUGcog provided for healthy Iranian adults increase the clinical utility of tests, and serve as a reference to estimating the individuals' balance performance across age and gender groups.

1. Introduction

Postural balance is the ability to remain steady by keeping the body's center of mass within the support base [1]. Balance impairments are not only reported in patients with neurologic diseases, but also they can be present in healthy people [2]. Balance impairment is correlated with an increased risk of falls and fall-related injuries [3]. Clinicians must evaluate the balance ability to find the people at risk of falls, which can lead to early intervention for at-risk populations [4].

There are many clinical tools in clinics and research to obtain more precise information about the subjects' balance. The functional Reach Test (FRT) is a static balance test showing maximum stability limits while reaching forward while standing [5]. The single-leg stance (SLS) test is a simple and quickly administered tool to assess static balance and functional ability [6,7]. Timed Up and Go (TUG) test is a simple, quick, and practical balance test used to assess functional ability and physical mobility [8]. The TUG with the cognitive dual-task (TUGcog) is a version of the TUG test that assesses an individual's ability to perform two tasks simultaneously (performing a cognitive task while completing the TUG test). TUGcog can affect the balance and is thus useful in identifying people at risk of falls [9].

There are differences in the performance of balance tests and normative values among populations reported in different countries as different populations might have different characteristics affecting the balance controls. Moreover, there are no normative values available for healthy Iranian adults on the clinical balance tests, and findings from other countries might not be applicable to Iranians. Therefore, the

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Abbreviations

BESTest	Balance evaluation systems test
CI	Confidence interval
FRT	Functional Reach Test
SD	Standard deviation
SLS	Single leg stance
TUG	Timed Up and Go
TUGcog	Timed Up and Go with the cognitive dual-task

present study aimed to determine the normative values of selected balance tests (FRT, SLS, TUG, TUGcog) across age and gender groups in healthy Iranian adults.

2. Methods

2.1. Design

A cross-sectional study was designed. The study protocol was approved by the Students' Scientific Research Center and the Ethics Committee of Tehran University of Medical Sciences (ethical code: IR. TUMS.REC.1394.1512). All participants gave their written or oral informed consent before testing initiation. This work has been reported in line with the STROCSS criteria [10]. This study was also registered to www.researchregistry.com (unique identifying code: researchregistry7849).

2.2. Subjects

Community-dwelling adults were recruited from Tehran's public places such as mosques, parks, factories, and universities using convenience sampling. Subjects were represented in six age groups (18–29 years, 30–39 years, 40–49 years, 50–59 years, 60–69 years, ≥70 years).

Based on the previous reports [11,12], the sample size was estimated at 240 subjects. Considering that we had six age groups, 40 subjects (20 men and 20 women) were included in each age group.

The inclusion criteria were: 1) age ≥18 years; 2) living independently in the community; 3) able to speak Persian 4) able to follow commands; 5) able to walk 6 m without any help; 6) giving written or oral consent to participate in the study.

The exclusion criteria were: 1) history of fainting, vertigo, or dizziness; 2) current use of medications causing dizziness; 3) past or current history of medical conditions affecting balance.

2.3. Procedure

We collected data from August 2015 to June 2016. Six raters evaluated the patients. Five raters were medical students, and one was a physiotherapist. The eligible subjects were invited to participate in the study while receiving a verbal explanation of the study aims and procedure. After obtaining consent, the participants were asked about their demographic characteristics, including weight, height, age, and gender, and their responses were recorded. Body mass index (BMI) was calculated according to the following formula:

$$BMI = weight\ (kg)/\ height\ (m)^2$$

We followed the instructions provided by the Persian version of the Balance evaluation systems test (BESTest) for FRT, SLS, TUG, and TUGcog tests to carry out the tests [13,14]. To avoid inter-rater differences and standardize the procedure, a training session was undertaken to provide the instructions for performing the balance tests based on the Persian BESTest manual and video.

For performing FRT, the subjects were asked to comfortably stand close to the wall and raise their arms to 90° with their fingertips positioned at the beginning of the ruler. They were then asked to reach forward horizontally as far as possible without lifting their heels, rotating the trunk, or touching the ruler. The maximum distance that the subject had reached was measured (up to 50 cm). The subjects performed the test twice, and the best performance was recorded as a test score in centimeters.

For evaluation of the SLS test, the subjects were asked to stand barefoot, hands on the hips, and stand on the test leg unassisted. We recorded the time in seconds from the time the subjects flexed one leg behind to when it touched the ground or their hands moved from the hips (max 60 s). The subjects performed the test twice, and the best performance was recorded in seconds as a test score. Testing the SLS was first carried out with the right leg.

For evaluation of the TUG test, subjects were asked to sit on a standard chair, stand up upon the rater's command GO, walk straight for 3 m, turn around, walk back to the chair, and sit down again on the chair altogether. We recorded the time in seconds from the command GO when the subject stands up to when seated completely on the chair.

TUG dual-task is a combination of a TUG test with a cognitive task. First, the practice was done by asking subjects to count backward from a number between 90 and 100 by threes. Then, the subjects were asked to perform the TUG test while counting backward by threes from a different number.

2.4. Data analyses

The statistical package SPSS software for Windows (version 16, SPSS Inc, Chicago, Illinois) was used for the data analyses. Descriptive statistics of mean and Standard deviation (SD) were calculated for all demographics and outcome variables. Kolmogorov-Smirnov test was used to determine the normality. The Kruskal-Wallis test determined the differences between age groups if a variable was not normally distributed. The Mann-Whitney *U* test was used to determine the differences between genders in age groups. The significance level was set at $p \leq 0.05$.

3. Results

Descriptive statistics of the demographic data (weight, height, and BMI) for six age groups are located in Table 1. The ages across groups ranged from 20 to 86 years ($N = 240$).

Normative values of FRT, SLS, TUG, and TUGcog tests across age groups and genders are shown in Table 2 and Table 3, respectively (see Table 4).

For FRT, the mean values decreased with age. The mean values observed for the age groups ranging from 30 to 59 years were significantly less than those of 18–29 years and greater than those of older adults ≥60 years ($p < 0.05$). The FRT mean values significantly differed between older adults (age groups ≥60 years) and other age groups.

The mean values of the SLS test decreased with age for both legs. The mean values of the SLS test for younger and middle age groups (18–59 years) were significantly better than those of older adult groups (≥60 years)($p < 0.001$). The mean values of the SLS test were significantly different between the two older groups, with those who were 60–69 years having better performances than those who were ≥70 years (right leg 35.0 vs. 14.6, $p < 0.001$; left leg 30.4 vs. 13.4, $p < 0.001$).

The mean values for the TUG decreased with age, with the best mean for the age group of 18–29 years (6.4 s) and the worst mean for the age group of ≥70 years (11.8 s, Table 2). At the same time, the performance on the TUG was significantly worse for the≥70 years age group compared to other groups ($p < 0.001$). Also, the mean values of TUG for the 60–69 age group (8.1 s) were significantly worse than those for the 18–29 age group (6.4 s; $p = 0.037$).

For TUGcog, the mean values decreased with age. The best mean value was observed for the age group of 18–29 years (7.2 s), and the

Table 1
Descriptive statistics of demographic data for six age groups (N = 240).

	18–29 years (n = 40)			30–39 years (n = 40)			40–49 years age (n = 40)			50–59 years (n = 40)			60–69 years (n = 40)			≥70 years (n = 40)		
	Mean	SD[a]	Min-max	Mean	SD[a]	Min-max	Mean	SD[a]	Min-max	Mean	SD[a]	Min-max	Mean	SD[a]	Min-max	Mean	SD[a]	Min-max
Age (year)	22.5	2.3	20.0–29.0	33.3	2.6	30.0–39.0	45.1	3.0	40.0–49.0	54.3	3.1	50.0–59.0	64.2	2.3	60.0–68.0	74.4	4.0	70.0–86.0
Weight (kg)	67.9	13.3	50.0–115.0	72.0	15.3	50.0–109.0	71.5	13.3	50.0–113.0	71.6	13.0	54.0–110.0	71.7	11.1	52.0–99.0	70.0	9.8	41.0–94.0
Height (cm)	170.0	9.5	152.0–195.0	168.3	8.8	150.0–185.0	167.4	8.6	155.0–188.0	166.4	8.5	145.0–190.0	165.3	7.7	150.0–176.0	166.1	8.5	145.0–185.0
BMI	22.4	3.1	18.7–30.5	25.4	4.9	19.5–44.0	25.5	4.0	18.8–36.1	25.9	3.7	19.7–34.0	26.2	3.6	19.8–34.3	25.3	3.3	16.9–32.2

[a] SD, standard deviation.

Table 2
Normative values of FRT[a], SLS[b], TUG[c] and TUGcog[d] across age groups.

	18–29 years age group (n = 40)			30–39 years age group (n = 40)			40–49 years age group (n = 40)			50–59 years age group (n = 40)			60–69 years age group (n = 40)			≥70 years age group (n = 40)			Kruskal-Wallis test	
	Mean	SD[d]	95% CI	Mean	SD[d]	95% CI	Mean	SD[d]	95% CI	Mean	SD	95% CI	Mean	SD[d]	95% CI	Mean	SD[d]	95% CI	F	p
FRT[a] (cm)	37.3	7.44	34.89-39.65	32.1	7.7	29.6–34.6	30.8	7.1	28.5–33.0	31.6	8.1	20.0–34.2	26.1	7.8	23.6–28.5	24.3	7.3	22.0–26.7	15.0	**<0.001**
SLS[b]-right leg (sec)	56.4	8.8	53.5–59.2	47.0	16.5	41.7–52.2	49.9	16.7	44.5–55.3	50.0	17.2	44.5–55.5	35.0	22.0	28.0–42.0	14.6	17.0	9.1–20.0	32.7	**<0.001**
SLS[b]-left leg (sec)	56.7	8.69	53.9–59.4	46.5	15.4	41.6–51.4	51.1	15.4	46.2–56.1	48.0	18.0	42.3–53.8	30.4	22.5	23.2–37.6	13.4	16.7	8.0–18.7	37.7	**<0.001**
TUG[c] (sec)	6.4	1.86	5.8-7.0	7.1	1.8	6.5–7.7	7.7	2.1	7.0–8.3	7.3	2.2	6.6–8.0	8.0	2.2	7.3–8.7	11.8	3.4	10.7–12.9	26.7	**<0.001**
TUGcog[d] (sec)	7.2	2.21	6.5–7.9	8.7	2.2	8.0–9.4	10.6	3.8	9.4–11.8	10.8	3.5	9.6–11.9	11.7	3.2	10.6–12.7	16.9	5.6	15.1–18.7	33.5	**<0.001**

[a] FRT, functional reach test.
[b] SLS, single leg stance.
[c] TUG, timed up and go.
[d] TUGcog, timed up and go with cognitive dual task; SD,standard deviation.

Table 3
Mean normative values of FRT[a], SLS[b], TUG[c] and TUGcog[d] in male (M) and female (F) across age groups.

	18–29 years (n = 40)			30–39 years (n = 40)			40–49 years (n = 40)		
	M	F	p	M	F	p	M	F	p
FRT[a] (cm)	37.8 (7.1)	36.8 (7.8)	0.8	32.6 (7.5)	31.7 (8)	0.7	30.6 (9.2)	30.9 (4.4)	0.9
SLS[b] right leg (sec)	56.9 (7.8)	55.9 (9.8)	1.0	43.3 (16.8)	50.7 (15.7)	0.1	50.6 (16.8)	49.2 (17.1)	0.7
SLS[b] left leg (sec)	58.0 (7.1)	55.4 (10)	0.2	42.1 (16.2	51.0 (13.4)	**0.047**	53.0 (14.9)	49.3 (16.1)	0.6
TUG[c] (sec)	5.5 (1.3)	7.3 (1.9)	**0.002**	7.1 (2)	7.1 (1.7)	0.6	8.4 (1.8)	7.0 (2.1)	0.1
TUGcog[d] (sec)	6.2 (2)	8.2 (2)	**<0.001**	8.6 (2.5)	8.8(1.8)	0.4	11.1 (3.8)	10.0 (3.8)	0.3

	50–59 years (n = 40)			60–69 years (n = 40)			≥70 years (n = 40)		
	M	F	p	M	F	p	M	F	p
FRT[a] (cm)	33.5 (8.3)	29.75 (7.610	0.1	30.9 (6.2)	21.3 (6.1)	**<0.001**	26.7 (6.1)	22.0 (7.8)	**0.05**
SLS[b] right leg (sec)	57.3 (6.1)	42.8 (21.4)	0.1	45.0 (19.8)	25.0 (19.8)	**0.004**	22.2 (19.5)	6.9 (9.6)	**0.004**
SLS[b] left leg (sec)	52.8 (12.9)	43.3 (21.2)	0.3	41.0 (19.9)	19.8 (20.2)	**0.004**	20.0 (19.1)	6.8 (10.7)	**0.008**
TUG[c] (sec)	7.11 (1.7)	7.5 (2.7)	0.8	8.0 (1.7)	8.1 (2.6)	0.684	10.5 (2.6)	13.1 (3.7)	**0.02**
TUGcog[d] (sec)	10.69 (2.4)	10.8 (4.4)	0.6	11.3 (2.6)	12.0 (3.7)	0.881	14.7 (3.6)	19.1 (6.4)	**0.009**

[a] FRT, functional reach test.
[b] SLS, single leg stance.
[c] TUG, timed up and go.
[d] TUGcog, timed up and go with cognitive dual-task.

Table 4
Association between anthropometric measures and balance tests' values.

	Functional reach test	Right single-leg stance	Left single-leg stance	Timed up and go	Timed up and go with cognitive dual-task
Weight	0.002	0.007	0.004	−0.05	−0.046
Height	0.342***	0.222**	0.218**	−0.192**	−0.223**
BMI	−0.231***	−0.167**	−0.163**	0.083	0.112

*P < 0.05.
***P < 0.01.
***P < 0.001.

worst mean value was found for ≥70 years age group (16.9 s) ($p < 0.05$, Table 2). However, the TUGcog performances were not significantly different in the 18–29 and 30–39 age groups ($p > 0.05$).

There was no correlation between weight and performance in balance tests. There was a positive correlation between higher height and better performance in FRT, TUG, TUGcog, and SLS tests ($P < 0.01$). Also, there was a negative correlation between BMI and performance in FRT and SLS tests ($P < 0.01$).

4. Discussion

The present study provides normative values for selected tests of FRT, SLS, TUG, and TUGcog by age and sex, based on measurements in healthy Iranian adults without any condition affecting their balance. Normative data provided in this study would be beneficial for clinicians and researchers in general and Iranians in particular as they can now compare the balance tests' values reported in this study in individuals with or without balance dysfunctions to the normative reference values established based on healthy Iranian people.

4.1. FRT

We found that the performance on FRT decline with advancing age, which is consistent with previous studies demonstrating age-related reductions in FRT distance [15–19]. Poorer performances on FRT with age might be due to structural changes with aging [20,21] and decreases in plantar flexor muscle strength, which is associated with a decrease in stability limits [22]. A study recommended a normative value for FRT in older adults at 27.2 (SD 0.9, 95% CI 25.5–28.9 cm) based on the INFINITY and other 20 studies evaluating FRT values among adults [21]. Based on an analysis of a Canadian sample of 2305 older adults, the median value for FRT was 29 cm [23]. In our sample, the older adults in the age groups 60–69 years (mean 26.1) and ≥70 years (mean 24.3) had FRT mean values less than those recommended for older adults. In the current study, the sample of elderly subjects was small, and further studies with a larger sample of Iranian elderly subjects are required to confirm the findings.

4.2. SLS

We found that SLS test scores worsened with age, and the younger and middle-aged groups performed on the SLS test better than the older groups, which is consistent with previous reports [17,24,25]. Hip abductors, flexors, and extensors strength are associated with better performance on the SLS test [26]. In addition, musculoskeletal strength is crucial for the first 5 s of the SLS test [27]. The worst performance observed in older adult groups (≥60 years) and better performance in the 60–69 years age group than the ≥70 years group might be explained by decreased muscle strength around the hip with aging. Further, a study with 597 older adults found impairments in proprioceptive control, decreases in compensatory visual stabilization as well as adequate emergent responses in older adults as factors in the decline in stability limit on the SLS test [28].

Our normative values observed for the SLS test were higher than those reported by two previous reports [24,25]. A study with 549 subjects assessed in the groups of 18–39 years to 80–99 years found a significant decrease in the SLS, eyes opened, with aging, with the best trial found for female 18–39 years age group (mean 45.1 s) the worst trial recorded for male 80–99 years group (mean 8.7 s) [25]. Another study with 184 people in 6 age groups from 20 to 79 years found decreases in the ability of older subjects to stand on one leg, and mean values were ranged from max 30.0 s observed for the age groups of 20–29 and 30–39 years to min 14.2 s of 70–79 years [24]. This inconsistency might be explained by the fact that in previous works, the maximum time for balance on one leg was limited to 30 s [24] and 45 s [25], while we allowed a maximum time of 60 s for the SLS test.

The SLS test scores of fewer than 30 s, eyes opened or closed, are considered abnormal in individuals aged 20–79 years [24]. In the present study, in all age groups except the≥ 70 years age group, the meantime for SLST was higher than 30 s. This indicates that the older adults of the≥ 70 years age group in the present study had abnormal SLS scores and thus worst balance performance, which is in line with previous studies [29].

4.3. TUG

We found that TUG performance declined with age and older adults of 70≥ years had the worst scores. This finding is in line with previous studies demonstrating reductions in TUG performance as age advances [30–34]. A descriptive meta-analysis to define the reference values for TUG reported the mean TUG time (95% confidence interval) for individuals 60≥ years of age as being 9.4 (8.9–9.9) seconds [30]. The decline in mobility, physical activity, and changes in the neuromuscular system with aging may explain the increases in time for performing the TUG in the age group 70≥ [35].

We found significant differences between males and females in the 18–29 and ≥70 years age groups, and the male performed better than the female. This finding aligns with previous reports confirming the link between age and TUG performance [31,33,34]. A study on 98 women found similar worse performance in TUG for those aged ≥70 years and 40–59 years [36]. The worst performance on the TUG in women could be due to decreased mobility [37] and weakness in lower limb muscles, particularly in the older adult group [38]. However, the TUG test measures the interaction among various individual factors and systems involved in functional mobility [37]. Some diversity in reference norms reported for TUG in various countries could be due to the differences in height, weight, BMI, nutritional status, mental states of populations included in the studies, sample size, and methodology [32,33].

4.4. TUGcog

In this study, the TUGcog or TUG with cognitive dual-task took longer for completion, and performance in TUGcog declined with age, consistent with previous reports performed in healthy elderly adults [39]. This finding indicates that adding secondary tasks simultaneously with TUG prolonged the time, which was worse with increasing age. The worst TUGcog times in elderly adults indicate the fall risk in this population. Differences in TUGcog times across age groups observed in this study imply that the normative reference values should be age-specific.

In the current study, females performed better than males across age groups. However, a study with healthy, elderly community-dwelling people (n = 120) found no gender-specific differences in TUGcog performance [39]. Differences between the two studies might be due to the methodology, sample size, and population included.

4.5. Limitations

There are several limitations to this study. First, the sample size was small; thus, the generalizability of findings in the current study is limited, and future studies with larger sample sizes are suggested. Second, we only assessed subjects who lived in Tehran, the capital city of Iran, and the values may differ in other cities of Iran. However, Tehran is a giant city with people from various cities. Consequently, the sample in this study may be representative of the Iranian population, and normative values can be used for reference comparisons. Nevertheless, a study with a larger sample size with subjects recruited from representative cities of all states of Iran is recommended. Finally, we did not evaluate the risk of falls among our participants with different scores, which can be a practical use of these tests. Future prospective studies evaluating the risk of falls among Iranians using these tests may improve their utility.

5. Conclusions

The present study provided normative values for FRT, SLS, TUG, and TUGcog measured from healthy Iranian adults across age groups and genders. The normative values determined for these widely used balance tests will be useful in assessing subjects with balance problems and interpreting the findings based on the age and gender-specific reference values to make decisions about possible early interventions. Also, normative values provided by this study might be utilized in future studies evaluating balance among healthy adults and patients with different conditions as they can be a reference for comparisons.

Ethical approval

The study protocol was approved by the Student's Scientific Research Center and the Ethics Committee of Tehran University of Medical Sciences (ethical code: IR.TUMS.REC.1394.1512).

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This study was not funded.

Author contribution

Conceptualization: SN, ANA; Methodology: All authors; Formal analysis and investigation: ANA, NNA; Writing - original draft preparation: ANA, MG; Writing - review and editing: All authors; Funding acquisition: ANA, SN; Resources: All authors; Supervision: NNA; SN.

Registration of research studies

1. Name of the registry: researchregistry
2. Unique Identifying number or registration ID: researchregistry7849.
3. Hyperlink to your specific registration (must be publicly accessible and will be checked): https://www.researchregistry.com/browse-the-registry#home/registrationdetails/626a5e92c9d57e001f1eff3d/

Guarantor

Mohammad Ghafouri.

Consent

We obtained written consent from the participants prior to their participation in the study.

Provenance and peer review

Not commissioned, externally peer-reviewed.

Declaration of competing interest

Authors have no conflict of interest to declare.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.amsu.2022.104053.

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