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DETERMINATION OF AGE- AND GENDER-SPECIFIC REFERENCE VALUES FOR DIFFERENT FUNCTIONAL TESTS WITH OR WITHOUT COGNITIVE DUAL-TASK IN YOUNG ADULTS: AN OBSERVATIONAL STUDY

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ABSTRACT

Purpose: To determine the age- and gender-specific reference values for the five functional tests performed with or without cognitive dual-task in young adults.

Methods: In this cross-sectional observational study, a total of 107 participants were divided into four subgroups based on gender and age: females 18-25 years (G1), and 26-35 years (G2), and males 18-25 years (G3), and 26-35 years (G4). Participants completed the timed up and go test (TUG), 4 meter gait speed test, 10 meter walk test (10MWT), timed 25-foot walk test, and 1 minute sit-to-stand test (1MSTS) with and without dual-tasks. The mean value of each test was recorded.

Results: Significant differences were observed in some functional tests. TUG was longer in G1 compared to G2 (p=0.019), 10MWT dual-task performance differed between G1 and G3 (p=0.041), and 1MSTS and $1MSTS_{dual}$ scores were higher in G3 compared to G4 (p=0.044 and p=0.035, respectively). All dual-task conditions led to decreased performance compared to single-task conditions (p<0.001)

Conclusion: The dual-task added to the performance tests changes the time, speed, and number of repetitions in healthy individuals, and these effects may vary according to age and gender. These reference values can guide clinical assessments of dual-task performance in this population.

Keywords: Cognitive test, Multitasking behavior, Reference values, Task performance, Young adults

GENÇ YETİŞKİNLERDE BİLİŞSEL ÇİFT GÖREVLİ VE ÇİFT GÖREVSİZ FARKLI FONKSİYONEL TESTLERİN YAŞA VE CİNSİYETE ÖZGÜ REFERANS DEĞERLERİNİN BELİRLENMESİ: GÖZLEMSEL BİR ÇALIŞMA

ÖZ

Amaç: Genç yetişkinlerde bilişsel çift görevle ve çift görev olmadan gerçekleştirilen beş fonksiyonel test için yaşa ve cinsiyete özgü referans değerlerini belirlemektir.

Yöntem: Bu kesitsel gözlemsel çalışmada, toplam 107 katılımcı cinsiyet ve yaşa göre dört alt gruba ayrıldı: 18-25 yaş kadınlar (G1), 26-35 yaş kadınlar (G2), 18-25 yaş erkekler (G3) ve 26-35 yaş erkekler (G4). Katılımcılara zamanlı kalk ve yürü testi (TUG), 4 metre yürüme testi, 10 metre yürüme testi (10MWT), zamanlı 25 adım yürüme testi ve 1 dakika otur-kalk testi (1MSTS) çift görevle ve çift görev olmadan gerçekleştirildi. Her testin ortalama değeri kaydedildi.

Bulgular: Bazı fonksiyonel testlerde anlamlı farklılıklar gözlendi. TUG süresi G1'de G2'ye göre daha uzundu (p=0,019), 10MWT çift görev performansı G1 ile G3 arasında farklılık gösterdi (p=0,041) ve 1MSTS ile $1MSTS_{çift\ görev}$ skorları G3'te G4'e göre daha yüksekti (sırasıyla p=0,044 ve p=0,035). Tüm çift görev koşulları, tek görev koşullarına kıyasla performansın azalmasına yol açtı (p<0,001).

Sonuç: Sağlıklı bireylerde performans testlerine eklenen çift görev süre, hız ve tekrar sayısını değiştirmekte olup, bu etkiler yaş ve cinsiyete göre farklılık gösterebilir. Bu referans değerler, bu popülasyonda çift görev performansının klinik değerlendirmelerinde yol gösterici olabilir.

Anahtar Kelimeler: Kognitif test, Çoklu görev davranışı, Referans değerleri, Görev performansı, Genç yetişkinler

INTRODUCTION

Dual-task paradigm is a procedure that requires performing two tasks simultaneously in order to compare performance with single-task conditions and includes attention and executive function processes. Adding a cognitive task to motor performance testing also enables analysis of the relationship between cognitive and motor abilities (1,2). The significant deterioration in motor performance with dual-tasking indicates that additional demands of dual-task reduce the ability to perform at a basic level (3,4).

Mobility, which is defined as the ability to act independently in daily life, requires performing cognitive or motor tasks simultaneously and is affected by many different pathologies (3,5). Although functional tests are used to evaluate mobility, they may not be sufficient alone to reveal the level of mobility problems, especially when cognitive functions are also impacted. Individuals may exhibit near-normal mobility performance when cognitive processes are not added to the mobility tests and the assessment findings may not be adequate to reflect their complaints about daily life. Cognitive changes detected in many conditions with mobility problems reveal the importance of dual-task assessment (6-8). Especially "timed up and go (TUG)", "4 meter gait speed test (4MGST)", "10 meter walk test (10MWT)", "timed 25-foot walk test (T25FWT) and "1 minute sit to stand test (1MSTS)" are frequently used functional tests used in clinical practice and research (9,10).

Dual-task conditions can significantly affect motor performance in young adults and highlight the need for age- and gender-specific reference values for this population (11,12). However, the studies have primarily focused on parameters related to motor performance, such as postural control and muscle activity, and there is limited research on the dual-task performance of commonly used functional tests in young adults, including 4MGST, 10MWT, T25FWT, and 1MSTS. Reference values for the TUG test under dual-task conditions have been established for cognitively healthy adults, but these studies included only individuals over 50 years of age, and the reference values of this test under both single-task and dual-task conditions have not been investigated in young adults (13).

Dual-task paradigms are widely used to assess motor-cognitive interactions, yet the impact of gender on performance has not been thoroughly investigated. Previous studies have shown that women perform better on verbal and memory tasks, whereas men outperform women on spatial and mental calculation tasks (14-16). A more recent study reported that gender affects motor-cognitive performance in the dual-task TUG test, with men exhibiting lower cadence than women, women recalling more items in cognitive tasks, and men performing better in mental calculation tasks (17). These findings highlight the importance of considering gender in dual-task assessments; however, the influence of gender on commonly used functional tests in young adults remains scarcely investigated.

To determine the performance deterioration of patients, healthy norm values are essential. To interpret a test result, reference values should be collected from a healthy sample that matches the target population's characteristics, with consistent test procedures (18). Due to the heterogeneity of frequently used simple functional tests and protocol variations, it is important for clinicians and researchers to determine reference values based on dependent variables such as age and gender. Considering that pathologies which may affect functional capacity can afflict young adults as well as older individuals, and the necessity of comparing these patients with healthy individuals, normative data are needed for all age ranges regarding the functional capacities of healthy individuals.

This study aimed to determine the reference values for five commonly used functional tests performed with and without dual-task for young adults by age and gender. By considering the interaction between motor and cognitive tasks, these reference values will enable researchers and clinicians to use simple assessments to evaluate the impact of various pathologies and to determine intervention targets.

METHOD

Study Design and Participants

This study was conducted as an observational study between July 2022 and November 2022. After İstanbul University-Cerrahpaşa Clinical Research Ethics Committee approval (approval date: May 11, 2022, approval no: 2022/52) and ClinicalTrials.gov registration (NCT05373160) were completed, participants were informed and recruited after obtaining their written consent. The study was performed in İstanbul University-Cerrahpaşa, Department of Physiotherapy and Rehabilitation, by the principles of the Declaration of Helsinki. Participants were invited through campus-wide announcements, posters placed in university facilities, and social media. All volunteers contacted the research team directly and were screened for eligibility. Participants who were 18-35 years, were not diagnosed with musculoskeletal disorder, and volunteers were included. Participants were excluded if they had any history of knee, hip, or back pain that limited mobility; any recent musculoskeletal injury or lower extremity surgery within the last six months; any neurological condition; or a body mass index greater than 30 kg/m^2. The absence of cognitive impairment was confirmed through self-reported screening, and individuals reporting any cognitive or neurological problems or using assistive devices for walking were also excluded.

The minimum sample size was calculated to be at least 64 healthy individuals should be included in the study with an expected effect size: 0.30, power: 80% and error probability 0.05 (14) by using G*Power (version 3.1) software. Our study was completed with 107 participants. The 18-35 age range was divided into two subgroups (18-25 and 26-35 years) to reflect the transition from early adulthood to mature young adulthood, during which physical and cognitive performance may begin to show subtle differences. The flow diagram of the study is presented in Figure 1.

Outcome measures consisted of the five most commonly used tests to assess mobility and lower extremity functionality in many different conditions.

TUG: TUG assesses the ability to perform sequential motor tasks relative to walking and turning. Time was registered from when the person arised from an armchair, walked 3 meter, turned around, walked back, and sitted down again. A test trial was allowed, and two attempts were registered (19).

4MGST: 4MGST assesses walking speed. The participants were asked to walk at the best possible speed through the 1-meter "test" zone for acceleration, the central 4-meter "test" zone, and the 1-meter deceleration zone. Time was started with the first step on the 0-meter line, and stopped with the first leg after the 4-meter line. The result was recorded in meters per second (m/s) (20).

10MWT: 10MWT assesses the walking speed. The participants were asked to walk at the best possible speed in a 10-meter area. The time starts with the first step on the starting line and ends when crossing the finish line. The result was recorded in total seconds (21).

T25FWT: T25FWT assesses the walking speed like 4MGST and 10MWT. The participants were asked to walk the distance of 7.62 meters as fast as possible but without running. The time to complete the distance was recorded in seconds. A test trial was allowed, and two attempts were registered (22).

1MSTS: The 1MSTS was used to assess lower extremity functional strength and exercise capacity. Participants performed a one-minute repetition of standing and sitting from an armless chair with a height of 46 centimeters. Participants were not allowed to use their arms as support. The number of sit-ups performed for 1 minute was recorded (23).

Procedures

The participants completed TUG, 4MGST, 10MWT, T25FWT twice, without dual-tasks, respectively. Then, the same tests were completed twice with dual-tasks. Finally, 1MSTS was assessed without and with dual-tasks. Each test was started when the participants were ready for the next test. Thus, the learning effect for tests was minimized and the tests were standardized. The mean result value of each test was recorded.

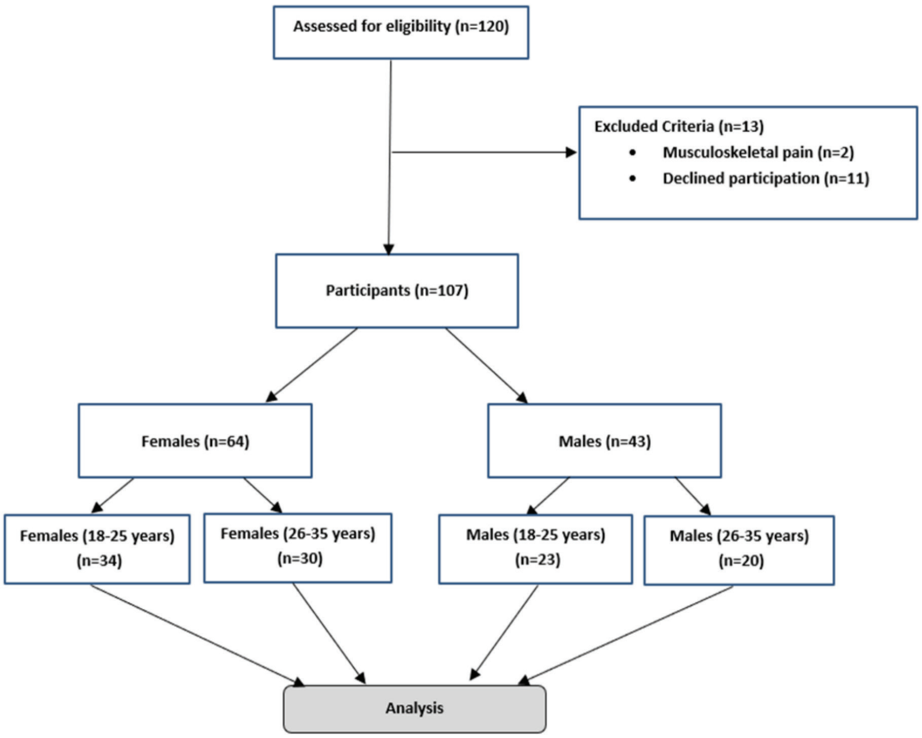

Figure 1. Flow diagram of the study.

Then, considering the interaction between both motor and cognitive tasks, reference values of TUG, 4MGST, 10MWT, T25FWT and 1MSTS for young adults with and without dual-task were calculated according to age and gender.

Dual-tasks

The participants performed tests with dual-task reported by the therapist. While there is no ideal dual-task, counting backwards and verbal fluency are reported to be the most used dual-tasks (2). The dual-tasks in this study were determined by examining the literature (13,24).

- TUG_{dual}: Saying the names of animals during TUG
- $4MGST_{dual}$: Counting down the months of the year starting from December during 4MGST
- $10MWT_{dual}$: Counting numbers back from 100 by threes during 10MWT
- $T25FWT_{dual}$: Counting numbers back from 100 by sevens during T25FWT
- $1MSTS_{dual}$: Counting city names during 1MSTS

During the functional tests performed, the correct information obtained from the dual-tasks was noted along with the test results. The cognitive tasks were selected according to the duration and complexity of each functional test, following previous studies (13,24). Verbal fluency tasks (e.g., naming animals, cities) were used for shorter tests to minimize interference, whereas arithmetic tasks (e.g., counting backward by 3s or 7s) were paired with longer walking tasks to provide a consistent cognitive load. This pairing aimed to balance motor and cognitive demands across tests. Errors made during the cognitive tasks were recorded; however, the tests were not stopped or repeated.

Statistical Analysis

All statistical analyses were performed using the Statistical Package for the Social Sciences (IBM SPSS Statistics® version 25, IBM Corp., Armonk, NY, USA). Descriptive statistics, including median (25^{th}-75^{th} percentile), mean, confidence interval (95%), standard deviation (SD), frequency, percentage, minimum, and maximum values were calculated for the functional test-specific results (m/s, s, number of sit-ups, and number of steps taken/overflowing). The normality of the data distribution was examined using histogram plots and the Kolmogorov-Smirnov test. Participants were divided into four subgroups based on sex and age: G1 (females 18-25 years), G2 (females 26-35 years), G3 (males 18-25 years), and G4 (males 26-35 years). Since the data were not normally distributed, differences across the four subgroups were analyzed using the Kruskal–Wallis test, followed by Dunn-Bonferroni post-hoc tests for multiple pairwise comparisons. For direct two-group comparisons, the Mann-Whitney U test was used. The primary comparisons of interest were between G1-G2, G1-G3, G2-G4, and G3-G4. Statistical significance was set at $p<0.05$.

RESULTS

A total of 120 individuals were screened for eligibility. Thirteen were excluded: two did not meet the inclusion criteria (due to musculoskeletal pain), and eleven declined to participate due to time constraints or lack of interest. Consequently, 107 participants (mean ± SD age, 25.23±4.08 years; 64 (58.80%) females) were included in the final analyses. All baseline demographics were demonstrated in Table 1.

Participants were divided into four subgroups based on sex and age: females 18-25 years (G1, n=34) and 26-35 years (G2, n=30), and males 18-25 years (G3, n=23) and 26-35 years (G4, n=20). In the total sample, all dual-task conditions led to decreased performance compared to single-task conditions (TUG, 4MGST, 10MWT, T25FWT, and 1MSTS; $p<0.001$) (Table 2).

In the single-task functional tests, significant differences were observed in TUG, with G1 taking longer than G2 (p=0.019). In dual-task conditions, 10MWT performance was significantly different between G1 and G3 (p=0.041), while 1MSTS and 1MSTS dual-task scores were higher in G3 compared to G4 (p=0.044 and 0.035, respectively). Other functional tests, including 4MGST, 4MGST dual, T25FWT, and T25FWT dual, did not show significant differences between subgroups ($p>0.05$).

Cognitive-motor dual-task performance, assessed by the number of correct responses during functional tests, showed subgroup differences in several tests. Significant differences were found in 4MGST (month) between G1-G3 and G3-G4 (p=0.01), 10MWT (number) (p=0.017), T25FWT (number) between G1-G2 (p=0.026), and 1MSTS (city) between G3-G4 (p=0.004) (Table 3).

Table 1. Demographic features of the participants

Characteristic total sample (n=107)	Mean ± SD (CI 95%)	Min-max
Age (years)	25.23±4.08 (24.45-26.02)	20-35
BMI (kg/m^2)	22.86±3.57 (22.18-23.55)	15.41-39.01
	Frequency (%)	
Gender		
Male	43 (40.19%)	
Female	64 (59.81%)	
Education status		
Highschool	14 (13.08%)	
Undergraduate	67 (62.62%)	
Graduate	26 (24.30)	

SD: Standard Deviation, CI: Confidence Interval, BMI: Body Mass Index, kg: Kilogram, m: Meter, Min: Minimum, Max: Maximum.

Table 2. Reference values of the participants without and with dual-task

	Total sample (n=107)				
	Test results median (25th-75th percentile)	Test results with dual-task median (25th-75th percentile)	p-value	Mean rank	Numbers of correct responses Mean ± SD
TUG (s)	5.48 (5.03-6.05)	5.94 (5.35-6.71)	**<0.001***	58.38	6.05±1.57
4MGST (m/s)	1.67 (1.34-1.93)	1.43 (1.15-1.86)	**<0.001***	53.68	3.23±1.32
10MWT (s)	5.39 (4.99-6.04)	6.61 (5.91-7.49)	**<0.001***	55.03	5.11±1.64
T25FWT (s)	4.31 (3.98-4.77)	5.63 (4.93-6.25)	**<0.001***	55.78	3.21±1.4
1MSTS	35 (30-40)	29 (26-35)	**<0.001***	53.50	26.54±6.25

*Statistical analysis was performed using the Wilcoxon signed-rank test. Significance was set at p<0.05.

TUG: Timed Up and Go Test, 4MGST: 4 Meter Gait Speed Test, 10MWT: 10 Meter Walk Test, T25FWT: Timed 25-Foot Walk Test, 1MSTS: 1 Min-Sit-to-Stand Test.

Table 3. Age- and gender-specific reference values of functional tests

	Groups						
	Female (n=64)		Male (n=43)				
	G1	G2	G3	G4			
	18-25 y females	26-35 y females	18-25 y males	26-35 y males	X^2 (df=3)	p-value	Group differences
	(n=34)	(n=30)	(n=23)	(n=20)			
	Median (25th-75th percentile)	Median (25th-75th percentile)	Median (25th-75th percentile)	Median (25th-75th percentile)			
Characteristic							
Age (years)	22 (21-22)	28 (27-30)	22 (21-23)	30 (28-31)			
Functional tests							
TUG (s)	5.78 (5.24-6.51)	5.51 (5.06-5.97)	5.55 (4.99-5.91)	5.19 (4.37-5.55)	9.95	**0.019**	G1-G2
TUG_{dual} (s)	6.33 (5.46-7.15)	5.92 (5.59-6.95)	5.79 (5.17-6.37)	5.67 (5.04-6.16)	6.76	0.08	NS
4MGST (m/s)	1.61 (1.27-1.82)	1.78 (1.48-2.11)	1.61 (1.25-1.84)	1.65 (1.14-2.11)	4.06	0.254	NS
$4MGST_{dual}$ (m/s)	1.27 (1.03-1.71)	1.46 (1.22-1.81)	1.41 (0.99-1.69)	1.53 (1.21-2.18)	3.88	0.275	NS
10MWT (s)	5.67 (5.07-6.02)	5.51 (5.22-6.14)	5.25 (4.73-5.92)	5.33 (4.55-5.83)	6.32	0.097	NS
$10MWT_{dual}$ (s)	7.01 (6.25-7.65)	6.86 (6.14-7.50)	5.99 (5.32-6.96)	6.14 (5.41-7.11)	8.26	**0.041**	G1-G3
T25FWT (s)	4.54 (4.14-4.88)	4.25 (4.01-4.79)	4.02 (3.81-4.51)	4.31 (3.69-4.74)	7.19	0.066	NS
$T25FWT_{dual}$ (s)	5.57 (5.15-6.27)	5.78 (4.93-6.54)	5.62 (4.45-6.21)	5.27 (4.31-6.19)	2.32	0.509	NS
1MSTS	36 (30-43)	34 (31-38)	39 (32-54)	33 (29-37)	8.07	**0.044**	G3-G4
$1MSTS_{dual}$	31 (26-37)	27 (25-31)	33 (28-40)	28 (23-32)	8.63	**0.035**	G3-G4
Median number of correct responses							
TUG (s)-animal	5 (4-7)	6 (5-7)	6 (4-7)	6 (6-7)	6.76	0.08	NS
4MGST (m/s)-month	3 (2-5)	4 (3-5)	2 (1-3)	3 (2-4)	11.34	**0.01**	G1-G3 G3-G4
10MWT (s)-number	4 (3-5)	6 (4-7)	5 (4-7)	5 (4-6)	10.25	**0.017**	NA
T25FWT (s)-number	3 (2-3)	3 (2-4)	3 (2-4)	4 (3-5)	9.24	**0.026**	G1-G2
1MSTS-city	25 (21-29)	27 (23-32)	24 (20-27)	31 (26-34)	13.38	**0.004**	G3-G4

Data are presented as median (25th-75th percentile). Comparisons among the four subgroups were performed using the Kruskal-Wallis test. When significant overall differences were detected, pairwise comparisons were conducted using the Dunn post-hoc test with Bonferroni correction. For direct two-group analyses, the Mann–Whitney U test was applied. Statistical significance was set at p<0.05.

TUG: Timed Up and Go Test, 4MGST: 4 Meter Gait Speed Test, 10MWT: 10 Meter Walk Test, T25FWT: Timed 25-Foot Walk Test, 1MSTS: 1 Min-Sit-to-Stand Test, G1: Females aged 18-25 years, G2: Females aged 26-35 years, G3: Males aged 18-25 years, G4: Males aged 26-35 years, NA: Not applicable, NS: Not significant.

DISCUSSION

This study presented reference values for the five frequently used functional tests with and without dual-tasks, as well as compared the results according to age and gender groups. It was shown that there is a decrease in functional performance with dual-tasks. The results of performance were lower in all tests with dual-tasks in females. There were significant changes in all other tests with dual-tasks in males except the 4MGST. Test performances were affected with dual-tasks in both age groups. Importantly, this study affirms that adding dual-task to a functional test affects performance in healthy subjects to a certain extent.

TUG is one of the most widely used clinical tool to evaluate mobility and fall risk in many different diseases (25). Adding cognitive dual-tasks which are similar to the daily life tasks to the TUG increases the precision of the test and its found to be more sensitive and specific to determining the rate of falling risk in the elderly (26). Despite it being a frequently used tool, normative values of the test with dual-task for young adults are limited in the literature. In our study, the test duration was prolonged when the cognitive dual-task of counting animal names was added to the TUG. While the TUG duration was different between the ages of 18-25 and 26-35, the performance of both age groups was similar in TUG_{dual}. Furlanetto et al. (27), determined the normative TUG duration in healthy people. Although the way our study grouped the ages was different, test duration of 20-29 and 30-39 age groups were parallel to our study but we also presented TUG_{dual}. Similar to literature, TUG duration in female was longer than male performance. It might be related to the differences in muscle strength and muscle contraction speeds between genders, which contribute to women walking more slowly (28,29). Also, men completed the TUG_{dual} in a shorter time than women. Due to the dual-task increased the attention and cognitive effort during function, the TUG performance time was prolonged with cognitive dual-task. It was also important to give the correct response to cognitive dual-task. While individuals aged 26-35 were able to name more animals during the TUG_{dual}, gender did not affect the number of correct repetitions.

In this study, 10MWT duration increased when the dual-task of counting backwards from 100 by threes was added. As combining cognitive and physical tasks was more demanding, the test duration increased for all participants which is expected as gait involves both physical and cognitive components (30,31). Due to cognitive task leading to disturbance to maintain a motor task, gait was slower in the $10MWT_{dual}$ and test completion were longer than in those without dual-task (30,32). The 10MWT, and $10MWT_{dual}$ duration increased in the 26-35 age range compared to the 18-25 age range. Krampe et al. (33) showed that dual-task decreases performance due to dual-task costs increase in older age groups. Also, a previous study reported that motor task prioritization in dual-task performance was commonly seen in older age groups compared to younger ones (34). Unlike these consequences, the present study revealed that participants who are in the older age group have greater mean numbers of correct responses because of prioritized cognitive performance rather than the motor task. We think that this may related to the high level of education of the participants. Gender was also a determinant factor in test results. It was revealed that test completion time of the males were lower than females with and without dual-task. However, there was no difference in terms of the correct number of repetitions between women and men. Consistently with the present study, Paker et al. (35) reported that the female gender has a slower gait speed than the male gender. Another study showed that, whether customary speed or fast speed was determined, gait speed in 10MWT was slower in the female gender (36).

T25FWT is one of the tests used clinically for the determination of walking dysfunction and prognosis determination in patients with multiple sclerosis (MS), where cognitive disorders are frequently seen (37). Our study revealed that, T25FWT was another functional test that has significantly increased test duration when a dual-task as counting numbers back from 100 by sevens, was included. Phan-Ba et al. (38) found that an average T25FWT duration of 3.70 seconds in 104 healthy individuals with mean age 35, 5.81 seconds in people with MS with an expanded disability status scale (EDSS) score between 4-5.5, and 4.50 seconds with an EDSS score of 2.5-3.5. In our study, the average duration was 4.40 seconds for T25FWT, and 5.77 seconds for $T25FWT_{dual}$. Our study provides age- and gender-specific normative values for the both T25FWT, and $T25FWT_{dual}$, which are not available in the literature. While females had slower T25FWT performance than men, there was no difference between females and males in $T25FWT_{dual}$. There was also no significant difference between age groups both T25FWT and $T25FWT_{dual}$.

Bohannon and Wang (20) determined the normative values of 4MGST in adults aged 18-85 years and found the highest result at 1.85 m/s in men aged 18-29 years. In our study, the mean of 4MGST in women was 1.75 m/s, and the mean of $4MGST_{dual}$ was 1.50 m/s. The mean 4MGST and $4MGST_{dual}$ for men were 1.63 and 1.60, respectively, while there was no difference between males and females. On the other hand, $4MGST_{dual}$ performance of men was lower than women, with an average of 2.84 words. According to these results, the lack of difference between men and women may be due to the lower task performance of men during the $4MGST_{dual}$ (19). Also, since the 4MGST is a very short test and the walking speed of men is higher than women, we think that ending the test without creating enough correct response may explains the significant difference in the number of responses between genders.

Reference values of 1MSTS are required to appropriately evaluate sit-to-stand test result and to identify individuals with lower exercise capacity. While there were no significant differences between male and female participants in 1MSTS, and $1MSTS_{dual}$ performance, 26-35 age group generally performed less well than the 18-25 age group. Adding a cognitive dual-task resulted in an average of 16.13% reduction in 1MSTS performance in the entire population. Haile et al. (39) reported 1MSTS test reference values for children and adolescents, revealing that performance in girls and boys was similar, and younger age groups performed better consistent with our results. Vilarinho et al. (40) determined the reference values of the 1MSTS test for the Portuguese population between 18-95 age and stated that there were three more repetitions in favor of males than females, and that performance declined with age.

Limitations

This study has some limitations. The reference sample was mostly recruited in a university city, and their relatively high educational level could have affected the results. This may have contributed to a higher baseline cognitive performance and limited the variability of the results, potentially affecting generalizability to broader young adult populations with different educational or socioeconomic backgrounds. Future studies including participants with more diverse educational and occupational profiles are recommended to enhance external validity. Furthermore, in addition to age and gender, other factors such as physical activity level, body mass index, and cognitive performance may have influenced the results. These variables represent potential sources of variability beyond the primary demographic characteristics and should be considered when interpreting the findings. The lack of any standard for the chosen cognitive dual-tasks is another limitation. Although the study used commonly applied cognitive tasks from the literature, there is still no universally accepted standard for dual-task paradigms. Future research should focus on developing and validating standardized cognitive task protocols that can be matched to different functional performance tests. The different cognitive tasks used in this study introduced varying cognitive loads, which may have influenced the degree of dual-task interference. For instance, tasks involving mental arithmetic (e.g., counting backward) typically demand greater working memory and attentional resources than verbal fluency tasks (e.g., naming animals or cities). The observed decline in performance across all conditions suggests that both motor slowing and cognitive prioritization may have contributed to the dual-task costs. This heterogeneity reflects real-world variability in cognitive–motor interactions but also limits direct inter-test comparability and clinical generalization. Future research also should focus on developing standardized dual-task paradigms with well-defined cognitive loads to enhance cross-study consistency and clinical applicability.

Moreover, the external validity of our study is limited. Considering the participants were mostly university students or graduates, and having a relatively high educational level, this factor may have affected their cognitive task performance, as individuals with higher education tend to demonstrate better attention and processing speed during dual-task conditions. Therefore, the reference values reported here may not be directly generalizable to populations with a lower educational level. Future studies including participants from diverse educational and socio-economic levels are proposed to enhance the external validity of these findings.

Our study also has several strengths. Our study is the first in the literature in which the reference values for five of the most used functional tests were presented without and with dual-tasks in healthy young adults. At the same time, our study provided a framework for applying dual-task in functional tests. A major strength of this study is that it provides age- and gender-specific reference values for multiple functional tests performed both with and without cognitive dual-tasks in healthy young adults—a population that has been underrepresented in previous research. The results of the study provide reference values of TUG, 4MGST, 10MWT, T25FWT, and 1MSTS tests applied with and without cognitive dual-task in healthy young adults. We think that determining the reference values of these tests in healthy individuals will form a basis for functional capacity assessments in other diseases. The findings emphasize that even in a young, healthy cohort, adding a cognitive component significantly alters functional performance. Clinically, these normative data can serve as a reference for interpreting dual-task performance in neurological, orthopedic, or cognitive rehabilitation settings, helping clinicians to distinguish between normal and pathological performance patterns. Future studies should extend this approach to other age groups and clinical populations to enhance generalizability and develop standardized dual-task protocols. Also, reference values for functional capacity tests with or without cognitive dual-task should be determined for different age groups and different disease populations in future studies. Furthermore, functional capacity assessments performed with cognitive dual-tasks as an outcome measure, especially in dual-task applications will provide more valuable data for the efficacy of the intervention. From a clinical perspective, the age- and gender-specific reference values presented in this study can be used as a benchmark for evaluating dual-task performance in young adults. Clinicians may use these normative data to identify deviations from expected performance, monitor progress during rehabilitation, and design interventions that address dual-task deficits in neurological, orthopedic, or cognitive disorders. Moreover, in clinical practice, subtle functional or cognitive impairments in young adults—such as those associated with neurological, autoimmune, or metabolic disorders—may remain undetected in simple single-task assessments due to cognitive reserve. The dual-task reference values established in this study may therefore provide more sensitive benchmarks for detecting performance alterations and monitoring early functional decline in this population. In this sense, reference values for functional capacity tests applied with cognitive dual-task will make a significant contribution to the literature.

CONCLUSION

As a conclusion, our results revealed age- and gender-specific reference values of TUG, 4MGST, 10MWT, T25FWT, and 1-MSTS tests applied with or without cognitive dual-task in healthy young adults.

Ethics: İstanbul University-Cerrahpaşa Clinical Research Ethics Committee approval (approval date: May 11, 2022, approval no: 2022/52).

Informed Consent: Participants were informed and were recruited after obtaining their written consent.

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Conflict of Interest: The authors declare that they have no conflict of interest.

Author Contributions: Concept- ÇEC, TPİ, HE, NGE, AAY, AA, EA, BAS, FG; Design- ÇEC, TPİ, HE, NGE, AAY, AA, EA, BAS, FG; Supervision- YAA; Resources and Financial Support- ÇEC, TPİ, HE, NGE, AAY, AA, EA, BAS, FG; Materials- ÇEC, TPİ, HE, NGE, AAY, AA, EA, BAS, FG; Data Collection and/or Processing- ÇEC, TPİ, HE, NGE, AAY, AA, EA, BAS, FG; Analysis and/or Interpretation- YAA, ÇEC, TPİ, HE, NGE, AAY, AA, EA, BAS, FG; Literature Search- ÇEC, TPİ, HE, NGE, AAY, AA, EA, BAS, FG; Writing Manuscript- ÇEC, TPİ, HE, NGE, AAY, AA, EA, BAS, FG; Critical Review- YAA, ÇEC, TPİ, HE, NGE, AAY, AA, EA, BAS, FG.

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