Research Report

Factors Contributing to Single- and Dual-Task Timed "Up & Go" Test Performance in Middle-Aged and Older Adults Who Are Active and Dwell in the Community

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Background. Dual-task Timed "Up & Go" (TUG) tests are likely to have applications different from those of a single-task TUG test and may have different contributing factors.

Objective. The purpose of this study was to compare factors contributing to performance on single- and dual-task TUG tests.

Design. This investigation was a cross-sectional study.

Methods. Sixty-four adults who were more than 50 years of age and dwelled in the community were recruited. Interviews and physical examinations were performed to identify potential contributors to TUG test performance. The time to complete the single-task TUG test (TUG_{single}) or the dual-task TUG test, which consisted of completing the TUG test while performing a serial subtraction task ($TUG_{cognitive}$) or while carrying water (TUG_{manual}), was measured.

Results. Age, hip extensor strength, walking speed, general mental function, and Stroop scores for word and color were significantly associated with performance on all TUG tests. Hierarchical multiple regression models, without the input of walking speed, revealed different independent factors contributing to TUG_{single} performance (Mini-Mental Status Examination score, $\beta=-0.32$), TUG_{manual} performance (age, $\beta=0.35$), and $TUG_{cognitive}$ performance (Stroop word score, $\beta=-0.40$; Mini-Mental Status Examination score, $\beta=-0.31$).

Limitations. At least 40% of the variance in the performance on the 3 TUG tests was not explained by common clinical measures, even when the factor of walking speed was considered. However, this study successfully identified some important factors contributing to performance on different TUG tests, and other studies have reported similar findings for single-task TUG test and dual-task gait performance.

Conclusions. Although the TUG_{single} and the $TUG_{cognitive}$ shared general mental function as a common factor, the TUG_{manual} was uniquely influenced by age and the $TUG_{cognitive}$ was uniquely influenced by focused attention. These results suggest that both common and unique factors contribute to performance on single- and dual-task TUG tests and suggest important applications of the combined use of the 3 TUG tests.

The Timed "Up & Go" (TUG) test involves rising from a seated position, walking 3 m, turning around, walking back, and sitting back down.[1] This test is a simple and quick measure of functional mobility and has excellent reliability among older adults who are healthy[1,2] and populations with different medical diagnoses.[3–5] The standardized administration procedures and minimal testing space requirements of the TUG test make it highly practical for clinical use and epidemiological research. Therefore, the TUG test has been commonly used to assess mobility function,[6] frailty risk,[7–9] intervention efficacy, and fall risk.[10]

The TUG test is a seemingly simple yet complex mobility measure because of its incorporation of sequential transferring and turning motor tasks.[11] Hence, studying the factors contributing to performance on a single-task TUG test (TUG_{single}) is of interest. Previous research identified several participant characteristics that contribute to TUG_{single} performance, including age,[12–14] sex,[13] body height,[12] body weight,[13] and previous fall histories.[12] Other factors, particularly motor (eg, lower limb strength, walking speed)[14] and cognitive (eg, general mental function)[12,13] variables, have also been reported to influence TUG_{single} performance.

In dual-task TUG tests, either a manual task, such as carrying a cup of water (TUG_{manual}),[15,16] or a cognitive task, such as a serial subtraction task ($TUG_{cognitive}$),[16] is commonly performed while the TUG test is carried out.[17] Previous research showed that the time difference in performance on dual- and single-task TUG tests is a valid predictor of frailty and falls.[15] It also has been reported that dual-task tests may have an added value for fall prediction over single-task tests.[15,18,19] A recent systematic review recommended selecting more complex tasks for fall prediction in populations with a relatively high level of functioning.[20] Therefore, dual-task TUG tests are likely to have applications different from those of the TUG_{single} and may have different contributing factors.

Although several studies used regression models to investigate factors contributing to dual-task level-ground gait performance, no previous studies specifically probed factors contributing to dual-task TUG test performance.[21–23] Hausdorff et al[21] identified executive function, attention, functional mobility, and affect as factors contributing to dual-task gait decrements in older adults who were healthy. Liu-Ambrose et al[22] reported important roles of attention shifting and walking speed in dual-task gait performance. Hall et al[23] documented that sex, quality of life, working memory, and walking speed contributed to dual-task gait performance. Although walking is a large component of the TUG test, performing the TUG test is more difficult than walking and is unique in its serial integration of several mobility tasks. Factors contributing to dual-task gait performance may not sufficiently explain dual-task TUG test performance. Given that single- and dual-task TUG tests are widely used in research and clinical settings, it is pertinent to understand whether different factors contribute to performance on single- and dual-task TUG tests.

We are unaware of any studies simultaneously investigating factors contributing to performance on single- and dual-task TUG tests. Therefore, this study was performed to explore the contributions of general participant characteristics and variables related to their motor and cognitive functions to performance on single- and dual-task TUG tests. We hypothesized that performance on all 3 types of TUG tests would be influenced by age and general mental function and that TUG_{manual} and $TUG_{cognitive}$ performance also would be influenced by attention and executive function. We also hypothesized that TUG_{manual} performance would be additionally influenced by strength or balance ability because participants had to maintain dynamic stability to avoid spilling water while transferring, turning, and walking.

Method

Participants

Participants were recruited from local communities of adults who were regularly participating in community center activities, including aerobic dance, calligraphy, and karaoke, for at least 1 h/wk. All participants traveled to the community center independently. These participants, therefore, were considered to be relatively active. The following 4 inclusion criteria were used: older than 50 years of age, living in the community, able to follow instructions, and able to walk independently in the community. The 2 exclusion criteria were diagnosis of central nervous system disease, such as stroke, Parkinson disease, or dementia, and an injury or musculoskeletal system disorder that would hamper the ability to perform physical tests. One person was excluded because she was unable to follow instructions, another was excluded because of his stroke history, and 3 other people refused to participate. A total of 64 participants met the criteria, signed the informed consent form approved by the Institutional Review Board of Chung Shan Medical University Hospital, and completed the study.

Procedure

During a single visit of approximately 60 minutes, each participant received a face-to-face interview performed by a trained researcher, tests of motor and cognitive variables administered by another researcher, and TUG tests administered by the other researcher. The interview, motor and cognitive tests, and TUG tests were performed in circuits. The participants were divided into 3 groups, with each group receiving the tests in a different order. During the face-to-face interview, the researcher extracted information about relevant participant characteristics, including age, sex, education (≤12 years, 13–17 years, or ≥18 years), fall history (yes/no) in the preceding 6 months, comorbidities, and body mass index. Comorbidities considered in this study were hypertension, diabetes mellitus, kidney disease, heart disease, asthma, cancer, back problems, arthritis, or dizziness. Body height and weight were measured to calculate body mass index.

Motor variables collected in this study were grip strength; strength of the hip, knee, and ankle muscles; performance on the Functional Reach Test[24]; and walking speed. Two trials of the maximum grip strength of the dominant hand were performed with a hydraulic handheld dynamometer (North Coast Hydraulic Hand Dynamometer, North Coast Medical Inc, Gilroy, California) and a standard protocol.[25] The grip strength test has been shown to have high test-retest reliability.[25] Two trials of the maximum isometric strength of the hip extensor, knee extensor, ankle dorsiflexor, and ankle plantar flexor of the dominant leg were performed with another hydraulic handheld dynamometer (MicroFET2, Hoggan Health Industries Inc, West Jordan, Utah) and a standard protocol.[26] The higher of the 2 strength measurements was used for subsequent analyses. The isometric strength test with this protocol has been shown to have high test-retest reliability.[26] The participants' balancing ability was assessed with the Functional Reach Test,[24] which has been shown to have good validity and reliability.[24] For the measurement of walking speed, the participants performed 3 walks at their usual pace along a 4.58-m walkway, which extended an additional 1 m at each end to allow for acceleration and deceleration. The average speed of 3 walking trials was determined. The measurement of walking speed has been shown to have excellent test-retest reliability.[27]

Cognitive variables collected included Mini-Mental State Examination (MMSE)[28] and Stroop test scores. The participants' general mental status was assessed with the MMSE.[28] The reliability and validity of the Chinese version of the MMSE have been established.[29] A Chinese version of the Stroop Color-Word Test,[30,31] translated by the authors, was used for testing specific cognitive functions. The Stroop test consisted of a word page, a color page, and a color word interference page. On the word page, which examines focused attention,[32] the participants were instructed to read aloud the words printed in black. On the color page, which examines information processing speed, the participants were instructed to read aloud the color of colored blocks. On the color word interference page, which probes response inhibition and executive function, the participants were shown a page of color words printed in incongruent ink colors and were instructed to name the ink color while ignoring the meaning of the words. The reliability of the English version of the Stroop Color-Word Test has been shown to be good,[33] but that of this translated version was not available.

Performance on the Stroop test was timed with a stopwatch, and errors were recorded. For each page, the performance score was calculated as: (accuracy × 100)/average time taken to answer each question (in %/ms). The accuracy indicated the number of correct answers as a percentage of the number of total answers on one page. The average time taken to answer each question was the total time to answer all of the questions on one page divided by the number of total answers on that page. Higher performance scores represented better performance.[32,34]

The participants also performed the TUG_{single} and 2 types of dual-task TUG tests. In the TUG_{single}, the participants were asked to stand up from a seated position, walk forward 3 m as quickly as possible, turn around, walk back to the chair, and sit down. In one of the dual-task TUG tests, the TUG_{manual}, the participants were asked to complete the TUG task while carrying a cup of water that was filled to 3 cm from the top of the cup. In the other dual-task TUG test, the $TUG_{cognitive}$, the participants were asked to complete the TUG test while counting backward by 3's from a randomly selected number between 80 and 99. We instructed the participants to best perform both tasks in the dual-task TUG tests so that we could observe their natural strategy in the context of divided attention. The time to complete each TUG test was recorded to the nearest 0.01 second with a stopwatch; the measurement began when the participant's back left the back of the chair and ended when the participant's buttocks touched the seat of the chair. One practice trial and 3 formal trials were performed for each TUG test; the average of 3 trials was analyzed. The order of the 3 TUG tests was randomized. A subgroup of 7 participants was invited to return 1 week later for a second measurement on the 3 TUG tests to determine test-retest reliability. The intraclass correlation coefficients for the TUG_{single}, TUG_{manual}, and $TUG_{cognitive}$ were .989 (95% confidence interval [CI]=.943, .998), .991 (95% CI=.935, .999), and .976 (95% CI=.878, .996), respectively.

Data Analysis

Data were analyzed with the SPSS statistical package (PASW Statistics 18.0, SPSS Inc, Chicago, Illinois). The one-sample Kolmogorov-Smirnov test was used to evaluate the normal distribution of each variable. To identify variables that were potential factors contributing to TUG_{single}, TUG_{manual}, and $TUG_{cognitive}$ performance, we calculated Pearson product moment correlation coefficients (r) for continuous variables with normal distributions and Spearman correlation coefficients (r_s) for continuous variables without normal distributions. Correlation coefficients of less than .25, between .25 and .50, between .50 and .75, and greater than .75 indicated little or no relationship, a fair relationship, a moderate-to-good relationship, and a good-to-excellent relationship, respectively.[35] Differences in TUG test performance on the basis of sex, education, fall history, and number of comorbidities for the participants were compared with independent sample t tests or one-way analysis of variance, as appropriate.

Continuous variables that exhibited significant correlations (with $P<.01$) with one type of TUG test performance and categorical variables that significantly influenced TUG test performance (with $P<.01$) were considered to be potential factors contributing to that TUG test performance. No multicollinearity among these potential factors was observed, as none of the variables showed correlations of greater than .7. Hierarchical multiple regression analyses were then performed to identify variables that were independent factors contributing to performance on each TUG test; the significance level was set at .05. In these regression analyses, general participant characteristics that were potential contributing factors were entered first, motor variables were entered next, and cognitive variables were entered last. We entered participant characteristics first in consideration of their potential general influence on the 3 types of TUG test performance. Previous studies with hierarchical multiple regression models placed participant characteristics at the top of the hierarchy.[23,36,37] We entered motor variables second because motor ability is required in all 3 types of TUG test performance. Cognitive variables were entered last because of their potential unique contributions to dual-task TUG test performance. Because walking is a large component of the TUG test and is known to be strongly related to TUG test performance[14] (as also found in this study), we did not include walking speed as a potential contributing factor in our primary regression models so as to reveal the influences of other variables. However, for comparison purposes, we conducted further regression analyses with walking speed as a potential factor in subsequent comparison models.

Role of the Funding Source

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Results

Sixty-four middle-aged and older adults who dwelled in the community participated in this study (mean age=71.6 years, SD=8.1) (Tab. 1). All of them were able to walk independently and continuously for at least 180 m from their homes to the community center. Most participants were women, had fewer than 12 years of education, and had less than one comorbidity. All participants met their age- and education-matched criteria (within 2 SDs of the means) for MMSE scores,[38] and they accurately answered an average of 4.0 questions on the serial 7 subtraction item of the MMSE. A history of falls was noted for 14.1% of the participants. The average body mass index was 24.7 kg/m^2 (SD=2.9).

Performance on the 3 TUG tests differed significantly (mean TUG_{single} time=8.3 seconds, SD=1.8; mean TUG_{manual} time=9.2 seconds, SD=2.3; mean $TUG_{cognitive}$ time=11.5 seconds, SD=4.7; $P<.001$ for all post hoc tests). With regard to the performance of the secondary task, in the TUG_{manual}, all participants successively stabilized the cup except for one participant, who spilled 1.8 g of water from the cup in 1 of 3 trials. In the $TUG_{cognitive}$, the average total number of answers per trial was 3.5 (SD=1.9, range=0–8.7), the average number of correct answers per trial was 3.3 (SD=1.9, range=0–8.7), and the average number of incorrect answers per trial was 0.2 (SD=0.4, range=0–2.0).

No significant difference in TUG_{single} performance ($P>.01$) was observed between participants on the basis of the 4 categorical variables (sex, education, fall history, and number of comorbidities). As shown in Table 2, correlation analyses revealed good associations of age ($r=.59$, $P<.001$), walking speed ($r=-.67$, $P<.001$), and Stroop word score ($r=-.51$, $P<.001$) with TUG_{single} performance but fair associations of hip extensor strength ($r=-.33$, $P=.008$), MMSE score ($r_s=-.45$, $P<.001$), and Stroop color score ($r=-.44$, $P=.001$) with TUG_{single} performance. Therefore, age, hip extensor strength, MMSE score, Stroop word score, and Stroop color score were considered to be potential factors contributing to TUG_{single} performance.

In the first step of hierarchical multiple regression, age was entered (Tab. 3). This model was statistically significant ($F_{1,49}=17.03$, $P<.001$) and explained 25.8% of the variance. Introduction of the motor variable, hip extensor strength, during the second step of the analysis explained 31.7% of the overall variance in TUG_{single} performance after controlling for age ($F_{2,48}=11.15$, $P<.001$). Introduction of the MMSE score, Stroop word score, and Stroop color score during the third step explained 44.9% of the overall variance ($F_{5,45}=7.35$, $P<.001$) and explained an additional 13.2% of the variance in TUG_{single} performance. In the final model, only one contributing factor remained statistically significant: MMSE score ($\beta=-0.32$, $P=.02$).

No significant difference in TUG_{manual} performance ($P>.01$) was observed between participants on the basis of the categorical variables. As shown in Table 2, correlation analyses revealed good associations of age ($r=.59$, $P<.001$) and walking speed ($r=-.68$, $P<.001$) with TUG_{manual} performance but fair associations of hip extensor strength ($r=-.36$, $P=.004$), MMSE score ($r_s=-.40$, $P=.001$), Stroop word score ($r=-.49$, $P<.001$), and Stroop color score ($r=-.41$, $P=.003$) with TUG_{manual} performance. Therefore, age, hip extensor strength, MMSE score, Stroop word score, and Stroop color score were identified as potential factors contributing to TUG_{manual} performance.

In the first step of hierarchical multiple regression, age was entered (Tab. 4). This model was statistically significant ($F_{1,49}=21.53$, $P<.001$) and explained 30.5% of the variance. In the second step of the analysis, introduction of the motor variable, hip extensor strength, explained 36.6% of the overall variance in TUG_{manual} performance ($F_{2,48}=13.83$, $P<.001$). Introduction of the MMSE score, Stroop word score, and Stroop color score during the third step explained 43.8% of the overall variance ($F_{5,45}=7.01$, $P<.001$) and explained an additional 7.2% of the variance in TUG_{manual} performance, an effect that was not significant ($F_{3,45}=1.93$, $P=.14$). In the final model, one potential factor remained statistically significant: age ($\beta=0.35$, $P=.01$).

No significant difference in $TUG_{cognitive}$ performance ($P>.01$) was observed between participants on the basis of the categorical variables. As shown in Table 2, correlation analyses revealed good associations of walking speed ($r=-.51$, $P<.001$) and Stroop word score ($r=-.59$, $P<.001$) with $TUG_{cognitive}$ performance but fair associations of age ($r=.42$, $P=.001$), MMSE score ($r_s=-.43$, $P<.001$), and Stroop color score ($r=-.47$, $P<.001$) with $TUG_{cognitive}$ performance. Therefore, the participant's age, MMSE score, Stroop word score, and Stroop color score were identified as potential factors contributing to $TUG_{cognitive}$ performance.

In the first step of hierarchical multiple regression, age was entered (Tab. 5). This model was statistically significant ($F_{1,50}=8.40$, $P=.006$) and explained 14.4% of the variance. Introduction of the MMSE score, Stroop word score, and

Table 1.
Demographics and Health Status of Participants[a]

Variable	Middle-Aged Adults (n=12)			Older Adults (n=52)			Total (N=64)		
	X̄	SD	Range	X̄	SD	Range	X̄	SD	Range
Participant characteristics									
Age (y)	59.5	3.1	52.6–63.3	74.4	6.1	66.4–87.1	71.6	8.1	52.6–87.1
BMI (kg/m^2)	24.6	3.2	18.9–31.3	24.8	2.8	18.6–30.1	24.7	2.9	18.6–31.3
Sex (no. of men/women)	3/9			20/32			23/41		
Education (no. of participants)									
≤12 y	2			40			42		
13–17	7			8			15		
≥18	3			4			7		
Fall history (no/yes)	11/1			44/8			55/9		
No. of comorbidities (no. of participants)									
0	4			17			21		
1	6			20			26		
2	1			12			13		
≥3	1			3			4		
Motor variables									
Grip strength (kg)	23.1	7.6	13.9–42.0	20.8	7.5	7.8–36.0	21.2	7.5	7.8–42.0
Isometric strength (kg)									
Hip extensor	14.5	3.4	9.8–20.1	13.5	3.2	7.3–20.1	13.7	3.2	7.3–20.1
Knee extensor	16.1	3.4	11.6–23.3	16.0	2.8	10.3–22.8	16.0	2.9	10.3–23.3
Ankle dorsiflexor	9.7	2.1	5.5–13.0	9.6	2.4	6.3–16.5	9.7	2.3	5.5–16.5
Ankle plantar flexor	12.0	2.3	8.2–15.4	12.4	3.0	7.8–20.7	12.3	2.8	7.8–20.7
Functional Reach Test (cm)	35.2	7.3	22.2–43.4	32.4	5.7	19.1–43.4	32.9	6.0	19.1–43.4
Walking speed (m/s)	1.2	0.2	0.7–1.6	1.1	0.2	0.6–1.5	1.1	0.2	0.6–1.6
Cognitive variables									
MMSE score (0–30)	28.4	1.1	27–30	26.3	3.0	19–30	26.7	2.9	19–30
Stroop score (%/ms)									
Word	21.2	6.4	10.5–33.0	15.7	5.3	2.7–25.8	17.0	6.0	2.7–33.0
Color	15.3	3.7	7.9–20.2	10.8	4.2	3.7–21.8	11.8	4.5	3.7–21.8
Interference	9.9	4.3	3.2–14.5	6.9	3.7	1.8–19.9	7.6	4.0	1.8–19.9
TUG test (s)									
Single task	7.5	1.4	5.1–11.3	8.5	1.8	4.6–14.0	8.3	1.8	4.6–14.0
Manual task	8.1	1.5	5.8–11.9	9.4	2.4	5.4–18.8	9.2	2.3	5.4–18.8
Cognitive task	9.4	2.1	6.7–14.0	12.0	5.0	5.9–35.4	11.5	4.7	5.9–35.4

[a] BMI=body mass index, MMSE=Mini-Mental State Examination, TUG=Timed “Up & Go.”

Stroop color score during the second step explained 43.1% of the overall variance ($F_{4,47}$=8.88, P<.001) and explained an additional 28.7% of the variance in $TUG_{cognitive}$ performance ($F_{3,47}$=7.89, P<.001). In the final model, 2 potential contributing factors remained statistically significant: Stroop word score, which had the higher β value (β=−0.40, P=.01), and MMSE score (β=−0.31, P=.02).

The comparison regression models, in which walking speed was entered as a potential contributing factor, revealed similar findings, except that walking speed was the primary important factor contributing to TUG_{single} performance (walking speed: β=−0.46, P=.001; MMSE score: β=−0.23, P=.06) and TUG_{manual} performance (walking speed: β=−0.45, P=.001; age: β=0.30, P=.02) and the third most important factor con-

Table 2.
Correlations Between Timed "Up & Go" (TUG) Test Performance and Continuous Measurements[a]

Variable	Correlation for TUG Test		
	Single Task	Manual Task	Cognitive Task
Participant characteristics			
Age	.59[b]	.59[b]	.42[b]
BMI	.30[c]	.31[c]	−.12
Motor variables			
Grip strength	−.23	−.28[c]	−.23
Isometric strength			
Hip extensor	−.33[b]	−.36[b]	−.33[c]
Knee extensor	−.20	−.25	−.32[c]
Ankle dorsiflexor	−.26[c]	−.17	−.26[c]
Ankle plantar flexor	−.09	−.07	−.17
Functional Reach Test	−.31[c]	−.30[c]	−.09
Walking speed	−.67[b]	−.68[b]	−.51[b]
Cognitive variables			
MMSE score[d]	−.45[b]	−.40[b]	−.43[b]
Stroop score			
Word	−.51[b]	−.49[b]	−.59[b]
Color	−.44[b]	−.41[b]	−.47[b]
Interference	−.25	−.28[c]	−.10

[a] BMI=body mass index, MMSE=Mini-Mental State Examination.
[b] $P<.01$.
[c] $P<.05$.
[d] Spearman correlation coefficient.

tributing to $TUG_{cognitive}$ performance in the final models (Stroop word score: $\beta=-0.31$, $P=.05$; MMSE score: $\beta=-0.27$, $P=.04$; walking speed: $\beta=-0.24$, $P=.06$). Including walking speed in the final models for the TUG_{single} and TUG_{manual} explained 58.0% and 56.5% of their overall variances, respectively. Removing the influence of walking speed allowed the significant contributions of other factors to TUG_{single}, TUG_{manual}, and $TUG_{cognitive}$ performance to be revealed.

Discussion

To our knowledge, the present study is the first to investigate how the characteristics and motor and cognitive functions of a sample of middle-aged and older adults who were relatively active and dwelled in the community influenced their performance on single- and dual-task TUG tests. Our original hypothesis that the TUG_{single}, TUG_{manual}, and $TUG_{cognitive}$ would have some common as well as other, different contributing factors was partially supported. Our results showed that the TUG_{single} and $TUG_{cognitive}$ shared general mental function as a common factor, whereas the TUG_{manual} was uniquely influenced by age and the $TUG_{cognitive}$ was uniquely influenced by focused attention.

Because walking is one of the primary tasks in TUG tests, we expected that comfortable walking speed would consistently exhibit a good correlation with performance on the 3 TUG tests (TUG_{single}, $r=-.67$; TUG_{manual}, $r=-.68$; and $TUG_{cognitive}$, $r=-.51$). Therefore, removing the influence of walking speed on TUG test performance in our primary regression analyses allowed the significant independent contributions of other factors to the TUG_{single}, TUG_{manual}, and $TUG_{cognitive}$ to be revealed. Similar negative relationships between walking speed and TUG test scores were reported in previous studies.[14,39] However, the correlation coefficients found in the present study were lower than those reported for patients with stroke ($r=-.90$)[39] and older people in institutions ($r=-.72$)[14]; these findings suggest that, unlike the situation in people with disability, walking ability alone accounted for less than half of the variance in TUG test performance for middle-aged and older adults who were active and dwelled in the community.

In addition to walking speed, age consistently showed a fair-to-good correlation with performance on the 3 TUG tests (TUG_{single}, $r=.59$; TUG_{manual}, $r=.59$; and $TUG_{cognitive}$, $r=.42$). This result aligns with a previous meta-analysis[40] that documented a clear relationship between age and TUG test performance. The fact that the participants in the present study had a wider age distribution (53–87 years old) may have resulted in correlation coefficients higher than those reported previously for older people in institutions (67–93 years old) ($r=.31$)[14] and adults who were healthy (70–90, 71–99, or 65–76 years old) ($r=.25$–$.28$).[11,13,22]

Partially consistent with the original hypothesis, the results of our regression analyses showed that the MMSE score—not age—was the primary independent factor contributing to TUG_{single} performance. Prior research also revealed that general mental function was associated with single-task TUG test performance in older adults dwelling in the community or in institutions.[12,13] The factor age may largely have covaried with the MMSE score, such that although age was significant in the second step of the multiple regression analysis, it became marginally insignificant when the MMSE score was taken into consideration in the final model ($\beta=-.20$, $P=.06$).

Partially consistent with the original hypothesis, our results showed that age—not any cognitive factor—was the primary independent factor contributing to TUG_{manual} performance. Univariate correlation analyses revealed significant correlations of MMSE and Stroop word and color scores with the TUG_{manual}.

Table 3.
Hierarchical Multiple Regression Models Determining Independent Predictors for Single-Task Timed "Up & Go" Test (TUG_{single}) Performance[a]

Step	R^2	B	β	P
1	.258			<.001
Age		0.11	0.51	<.001
2	.317			<.001
Age		0.10	0.46	<.001
Hip extensor strength		−0.13	−0.25	.05
3	.449			<.001
Age		0.06	0.26	.06
Hip extensor strength		−0.11	−0.20	.11
MMSE score		−0.26	−0.32	.02
Stroop word score		−0.04	−0.14	.40
Stroop color score		−0.01	−0.03	.87

[a] Walking speed was not considered as a potential factor. MMSE=Mini-Mental State Examination.

However, these cognitive factors may have covaried with other potential factors, especially age, such that they did not appear to independently additionally contribute to TUG_{manual} performance in the multiple regression analysis results. The findings that the TUG_{manual} was independently influenced not by any cognitive factor but by age and was uniquely associated with grip strength in univariate correlation analyses are new. We speculate that the TUG_{manual} may place more motor load rather than cognitive load on a person. Our results showed a weak yet significant relationship of grip strength with TUG_{manual} performance but no such relationship of grip strength with TUG_{single} or $TUG_{cognitive}$ performance. Previous research identified the TUG_{manual} as a more sensitive test than the other 2 tests for detecting prefrailty, probably because the TUG_{manual} demands some—although not maximum—sustained grip strength.[41]

Partially consistent with the original hypothesis, $TUG_{cognitive}$ performance, in contrast to TUG_{single} and TUG_{manual} performance, relied primarily on the cognitive abilities of the participants. Univariate correlation analyses revealed that the Stroop word score, Stroop color score, and MMSE score were the primary important factor and the third and fourth most important factors, respectively, associated with $TUG_{cognitive}$ performance. Regression analyses showed that the MMSE score and Stroop word score, which indicates focused attention, were the primary independent factors contributing to $TUG_{cognitive}$ performance. However, the Stroop interference score, indexing response inhibition and executive function, did not independently contribute to either $TUG_{cognitive}$ or TUG_{manual} performance. This finding may have been due to the fact that we instructed the participants to try to perform well on both tasks in the dual-task conditions. The participants were able to allocate their attention to both tasks, did not require a drastic shift of their attention, and did not need to limit their attention to one of the tasks. It also may be possible that only when the cognitive or motor task in the dual-task condition is of a higher level of difficulty to the participants will response inhibition or other executive functions—such as working memory[23] and set shifting[22]—become important factors contributing to their dual-task TUG test performance.

Table 4.
Hierarchical Multiple Regression Models Determining Independent Predictors for Manual Dual-Task Timed "Up & Go" Test (TUG_{manual}) Performance[a]

Step	R^2	B	β	P
1	.305			<.001
Age		0.17	0.55	<.001
2	.366			<.001
Age		0.15	0.50	<.001
Hip extensor strength		−0.18	−0.25	.04
3	.438			<.001
Age		0.11	0.35	.01
Hip extensor strength		−0.15	−0.21	.10
MMSE score		−0.25	−0.23	.09
Stroop word score		−0.06	−0.14	.40
Stroop color score		0.01	0.01	.95

[a] Walking speed was not considered as a potential factor. MMSE=Mini-Mental State Examination.

Finally, the finding of both common and differential factors contributing to TUG_{single}, TUG_{manual}, and $TUG_{cognitive}$ performance suggests important clinical applications of the combined use of single- and dual-task TUG tests for differentiating middle-aged and older adults whose functional mobility problems are due to different factors. The combined use of the TUG_{manual} and the TUG_{single} or the $TUG_{cognitive}$ may help identify people whose functional mobility problems are primarily due to poor cognitive functions versus old age. A person who performs well on both the TUG_{single} and the TUG_{manual} but poorly on the $TUG_{cognitive}$ is expected to have selectively poorer focused attention but to be relatively younger and to have relatively preserved general mental function. A person who performs well on both the TUG_{single} and the $TUG_{cognitive}$ but poorly on the TUG_{manual} is expected to be selectively

Table 5.
Hierarchical Multiple Regression Models Determining Independent Predictors for Cognitive Dual-Task Timed "Up & Go" Test ($TUG_{cognitive}$) Performance[a]

Step	R^2	B	β	P
1	.144			.01
Age		0.23	0.38	.01
2	.431			<.001
Age		0.03	0.06	.68
MMSE score		−0.70	−0.31	.02
Stroop word score		−0.33	−0.40	.01
Stroop color score		−0.03	−0.03	.84

[a] Walking speed was not considered as a potential factor. MMSE=Mini-Mental State Examination.

older but to have relatively preserved focused attention and general mental function. A person who performs well on both the TUG_{manual} and the $TUG_{cognitive}$ but poorly on the TUG_{single} is expected to have selectively poorer general mental function but to be relatively younger and to have relatively preserved focused attention. Inspection of our data revealed support for these expectations.

The present study had several limitations. First, the study was limited by the small convenience sample. The convenience sample represented middle-aged and older adults who were ambulatory and willing to participate in research and community-based activities. Therefore, the results can be generalized only to adults who are similar to our study population. A second limitation was that we did not explicitly provide instructions about task prioritization in dual-task TUG tests and did not record cognitive performance in the single-task condition. Hence, we were not able to examine changes in cognitive performance from single- to dual-task conditions and participants' task prioritization in the dual-task conditions. Whether older adults can change task prioritization according to instructions while performing dual tasks remains controversial. Oh-Park et al[42] reported that older adults who were healthy tended to adopt the walking-first strategy even when they were instructed to primarily attend to a secondary motor task while walking. However, other authors[43,44] reported that older adults could flexibly allocate attention to either the gait or the cognitive task. Third, participants' years of education and performance on the cognitive task alone were not investigated in the present study. The lack of such information may have influenced the interpretations and generalization of our findings with regard to the $TUG_{cognitive}$. However, the participants accurately answered an average of 4.0 questions on the serial 7 subtraction item of the MMSE and an average of 3.3 questions on the serial 3 subtraction task in the $TUG_{cognitive}$. These results suggest that the participants were capable of performing the cognitive tasks used in the present study. Fourth, the present study successfully identified some factors important in performance on different TUG tests. However, these factors explained only 43% to 45% of the variance in performance on the different TUG tests. Even when walking speed was considered in the regression models, at least 40% of the variance in performance on the 3 TUG tests remained unexplained by the common clinical measures used in the present study. These findings suggest that other factors need to be considered in the regression model in future analyses. Other studies also reported that approximately one-third of the variance in single-task TUG test[14] or dual-task gait[22,23] performance remained unexplained by similar common clinical measures. Future studies should explore a wider spectrum of variables, such as vision, vibration sense in lower extremities, coordination, working memory,[23] set shifting,[22] and variables in the affect domain,[21,22] to provide a better understanding of the mechanisms underlying performance on single- and dual-task TUG tests.

In conclusion, in the present study, independent factors contributing to performance on single- and dual-task TUG tests in a group of middle-aged and older people who were ambulatory, dwelled in the community, and actively participated in community-based activities were examined. The results suggest that the 3 TUG tests share walking speed as a common independent contributing factor and the TUG_{single} and $TUG_{cognitive}$ share general mental function as a common independent factor. The TUG_{manual} is uniquely independently influenced by age, and the $TUG_{cognitive}$ is uniquely independently influenced by focused attention. These results suggest potentially different applications for these 3 TUG tests. Previous meta-analyses revealed that the average TUG test performance time in African American and white people[40] was longer than that in Japanese people,[45] suggesting that different populations exhibit differences in TUG test performance. Future studies may be needed to further investigate the impact of ethnicity on factors contributing to single- and dual-task TUG test performance.

Both authors contributed to concept/idea/research design, writing, and data analysis. Dr Chen also contributed to data collection and project management.

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