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Original Article

Reliability and Minimal Detectable Change of Single- and Dual-Tasking Timed Up & Go Tests

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Purpose: This study aimed to determine the number of trials necessary for stable performance measuring-retest reliability, the minimal detectable change (MDC), and the construct validity of single- and dual-tasking Timed Up & Go Tests (TUG).

Methods and Results: This cross-sectional study recruited 66 adults aged 50 years and over who actively participated in local community programs. Time taken to complete single-tasking TUG (TUG_{single}) and dual-tasking TUG, carrying a cup of water (TUG_{manual}), or performing serial-3 subtraction ($TUG_{cognitive}$) while executing TUG, was measured three times each after one practice trial. Participants were interviewed for their previous history of falls. Frailty status was defined based on Fried's phenotypic definition. A subgroup of 7 participants was tested again after 1 week. Of the 7 participants (mean age= 69.5 ± 7.7 years), both the standard error of measurement (SEM) and MDC significantly dropped from the first trial to the mean of the first two trials, especially so for TUG_{manual}. Using the mean of three trials did not largely decrease SEM and MDC further, and it increased $TUG_{cognitive}$ values. Retest reliability (intraclass correlation coefficients; ICC) and MDC by using the mean of the first two trials were 0.994-0.965 and 0.37-1.53 seconds respectively. In the 66 participants (mean age= 71.6 ± 8.1 years), both TUG_{single} and TUG_{manual} were significantly correlated with degree of frailty and number of previous falls, and the coefficient remained significant after controlling for age in TUG_{manual} (0.269 and 0.263 respectively).

Conclusion: TUG_{manual} was found to have construct validity and high retest reliability, compared to TUG_{single} and $TUG_{cognitive}$ in community-dwelling middle-aged and older adults. It was found that by conducting two trials and taking the average of TUG_{manual}, retest reliability (ICC 0.965) could be optimized with MDC 1.53 seconds. These results, however, were based on a small sample and should be tested in further studies.

Key words: functional mobility, construct validity, reliability, minimal detectable change, frailty

Introduction

The Timed Up and Go test (TUG) was modified by Podsiadlo and Richardson from the Get Up and To test[1] which involves rising from a seated position, walking 3 meters, turning around, walking back, and sitting down[2]. The TUG test is a simple and quick measure of functional mobility. Its highly standardized administration procedures and its smaller space requirements make it highly practicable for clinical use and epidemiological

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research. Thus, the TUG test has been commonly used to assess functional mobility function[3], risk of frailty[4-6], and fall risk[7].

Dual-Task TUG tests, adding either a manual task such as carrying a cup of water (TUG_{manual})[8-10] or a cognitive task such as a serial-3 subtraction task ($TUG_{cognitive}$)[10], measure executive function on the platform of physical mobility[11]. Previous research has concluded that the time difference between dual- and single-tasking TUG is a valid marker of frailty and falls[9]. Furthermore, it has been reported that dual-tasking tests may have an added value for predicting falls than single-tasking tests[9,12,13]. A recent systematic review of fall prediction suggests heightening task complexity for relatively higher functioning populations[14]. Hence, dual-tasking TUG tests seem to have different applications from single-tasking TUG in various circumstances.

The single-tasking TUG test has excellent retest reliability among community-dwelling elderly (ICC 0.95-0.99)[2,15], elderly people with dementia (ICC 0.94-0.99)[16,17], and patients with Huntington disease (ICC 0.93-0.97)[18], and has good retest reliability among patients with Parkinson disease (ICC 0.69-0.85)[19-21]. Dual-tasking TUG_{manual} and $TUG_{cognitive}$ also have been shown to have excellent retest reliability among community-dwelling elderly (ICC 0.97-0.98)[22]. However, there are several unsolved questions regarding psychometric properties of single- and dual-tasking TUG tests. First, the minimal detectable change (MDC), which is the minimal amount of change between two points in time, which indicates a true statistical change[23], has not been reported for TUG tests among community-dwelling elderly. MDC reported for different etiologies varies greatly from 1.34 seconds in pre-manifest patients with Huntington disease[18], 4.09 seconds in elderly people with dementia[16], to 11 seconds in patients with Parkinson disease[20].

Secondly, while Podsiadlo and Richardson designed TUG test with one formal testing[2], some studies have used only one trial[8,19,21], some averaged two trials[15-18,20], and some have based their scores on the mean of three trials[10,22]. Dal Bello-Haas et al. has reported that the retest reliability of TUG in Parkinson disease could be improved from ICC 0.69 by using one trial data to ICC 0.76 by taking average of two trials[21]. The optimal number of tests to reach a stable performance measure remains unknown. Thirdly, although the construct validity of single-tasking TUG has been examined with regard to its relationship with the Berg Balance Scale, gait speed, and Barthel Index[2], the construct validity of dual-taking TUG tests has not been formally tested.

Therefore, the purposes of this study were to (1) investigate the retest reliability and MDC, (2) determine the optimal number of trials necessary for stable performance measure, and (3) examine the construct validity in both single- and dual-tasking TUG tests in a relatively active group of Taiwanese community-dwelling middle-aged and older adults.

Materials and Methods

Participants

Participants were recruited from local communities. Adults who participated in activities at community centers including aerobic dance, calligraphy and karaoke etc. were asked for their consent to participate. The inclusion criteria were: (1) aged 50 years or older, (2) living in the community, (3) able to follow instructions, and (4) able to walk continuously for at least 180 meters. The exclusion criteria were: (1) diagnosis of nervous system diseases such as stroke or Parkinson's disease and (2) recent injury or acute onset of disease of the musculoskeletal system that would hamper their ability to perform the physical tests. One person was excluded because she was unable to follow instructions, another was excluded due to a history of stroke, and another three persons refused to participate. A total of 66 participants who met the criteria participated in this study and signed informed consent forms. The protocol for this study was approved by the institutional review board of Chung Shan Medical University Hospital. A subgroup of seven participants was tested again after one week for evaluation of retest reliability.

Procedures

Participants were interviewed face-to-face to obtain demographic and health status information, including age, sex, education, history of falls within the previous 6 months, and number of co-morbidities. Co-morbidities included hypertension, diabetes mellitus, kidney disease, heart disease, asthma, cancer, back problems, arthritis, or dizziness in this study. In addition, body height and weight were measured, and the body mass index (BMI) was calculated. Participants' mental status was assessed using the Mini-Mental State Examination (MMSE)[24].

The five frailty indicators were operationalized as closely as possible to the phenotypic definition of Fried et al.[25]. First, the self-reported unintentional weight loss was indicated by more than three kilograms or greater than 5% of body weight loss in the previous year[26]. Second, exhaustion was indicated by a self-response of "more than 3 days a week" to either of the following statements: "I felt everything I did was an effort" or "I could not get going" on the Center for Epidemiological Studies-Depression Scale[25, 27]. Third, physical inactivity was measured by the Taiwan International Physical Activity Questionnaire-Short Form[28]. The criterion of the minimum weekly energy expenditure was 383 Kcal for men and 270 Kcal for women[25]. Fourth, slow walking speed was defined as a usual walking speed slower than the sex- and height-adjusted criterion-specific thresholds[25]. To measure walking speed, participants performed three walks at their usual pace along a 4.58-meter walkway, which extended one meter at both ends to allow for acceleration and deceleration. Fifth, weakness was indicated by grip strength below criterion-specific thresholds adjusting for sex and body mass index[25]. Two peak grip measures of the dominant hand were taken using a hydraulic hand-held dynamometer (North Coast Medical, Inc.). Each of the above frailty indicators, if present, contributed one point to the frailty coding, and a summary score was obtained from all five indicators. Participants scoring 0 were classified as nonfrail, 1-2 as prefrail, and 3-5 as frail[25].

Participants also performed the single-tasking and two types of dual-tasking Timed Up & Go tests. In the single-tasking TUG (TUG_{single}), participants were asked to stand up from a seated position, walk forward three meters as quickly as possible, turn around, walk back to the chair, and sit down. In one of the dual-tasking TUG tests, the TUG_{manual}, participants were asked to complete the TUG task while carrying a cup of water with the surface of water five cm from the top edge of the cup. In the other dual-tasking TUG test, the $TUG_{cognitive}$, participants were asked to complete the TUG test while counting backward by threes from a randomly selected number between 80 and 99. The time to complete the TUG tasks was measured by a stopwatch from when the participant's back left the back of the chair until when the participant's buttocks touched the seat of the chair. One practice trial and three formal trials were taken for each TUG test, conducted in random order. A subgroup of seven participants was invited to return one week later to perform the same TUG tests as described above to determine the retest reliability.

Statistical Analysis

Data were analyzed using PASW Statistics 18.0, and an alpha level of $P < 0.05$ was considered significant. Descriptive statistics were calculated. Retest reliability for all three TUG tests were determined using intraclass correlation coefficients, separately for the first trial data ($ICC_{2,1}$), the mean of the first two trials ($ICC_{2,2}$), and the mean of three trials ($ICC_{2,3}$). Retest reliability was considered poor if coefficients were < 0.50, moderate if coefficients were between 0.50 and 0.75, and good if values were > 0.75[29]. While coefficients > 0.70 were considered satisfactory for group-level comparisons, for individual comparisons and clinical decision making, reliability coefficient > 0.90 might be preferred to ensure valid interpretation of findings[29].

Absolute reliability, the measure of how an individual score varies on repeated measurement, was determined for all outcome measures using the standard error of measurement (SEM)[23]. Minimal detectable change, the minimal amount of change that is not due to variation in measurement[23], at a 95% confidence interval (MDC_{95}) was calculated by means of the following equation:

$MDC_{95}=SEM\times\sqrt{2}\times1.96$[23]

Construct validity of the TUG tests was examined by the relationship between the TUG tests and the number of frailty and of falls using Pearson product moment correlation coefficients. The partial correlation was used to examine if the relationship between the TUG tests and frailty and falls was affected by an underlying effect of age or not.

Results

For the subgroup of seven participants who were re-tested after one week, the mean age was 69.5 ± 7.7 years, four were female, the average number of co-morbidities was 1.1 ± 1.3, average BMI was 25.0 ± 2.1 kg/m^2, mean MMSE score was 28.4 ± 0.8, and average walking speed was 1.0 ± 0.1 m/s. The average time needed to perform TUG_{single}, TUG_{manual}, and $TUG_{cognitive}$ at baseline based on the mean of the first two trials was 7.51 ± 1.60, 8.29 ± 2.08 and 8.55 ± 1.25 seconds, respectively (Table 1).

As can be seen in Table 1, both SEM and MDC significantly dropped from the first trial to the mean of the first two trials. TUG_{manual} had the greatest amount of change, SEM -24.7% and MDC -24.3%. From the mean of the first two trials to that of all three trials, SEM and MDC decreased further (e.g. TUG_{manual} SEM -7.3%; MDC -7.8%) but not as much as from the first trial to the mean of the first two trials. SEM and MDC even increased from the mean of the first two trials to that of all three trials in $TUG_{cognitive}$. ICC also increased from the first trial to the mean of the first two trials. Based on the mean of the first two trials, ICCs for TUG_{single}, TUG_{manual}, and $TUG_{cognitive}$ were 0.994, 0.965, and 0.994 respectively, and the MDCs for TUG_{single}, TUG_{manual}, and $TUG_{cognitive}$ were 0.48, 1.53, and 0.37 seconds.

For the 66 participants whose data were analyzed for construct validity of TUG tests, the mean age was 71.6 ± 8.1 years, 43 were female, the average number of co-morbidities was 1.1 ± 0.9, average BMI was 24.8 ± 2.9 kg/m^2, mean MMSE score was 26.3 ± 3.4, and average walking speed was 1.1 ± 0.2 m/s. None of these participants was classified as frail. The prevalence of prefrailty was 57.6%. Twenty-eight had no frailty indicator, 33 had one frailty indicator, and five had two frailty indicators. Ten of the participants reported experiencing one fall, while another had three previous falls. The overall prevalence of falls in these participants was 16.7%.

As can be seen in Table 2, based on the mean of the first two trials, both TUG_{single} and TUG_{manual} were significantly correlated with the degree of frailty (r = 0.288 and 0.329 respectively) and number of previous falls (r = 0.272 and 0.295 respectively). $TUG_{cognitive}$ did not correlate with frailty or falls. After controlling for age, the correlation coefficients of TUG_{single} became insignificant, whereas the correlation between TUG_{manual} and degreee of frailty (r = 0.269) and number of falls (r = 0.263) remained significant.

Table 1. Descriptive and reliability measures of single-tasking Timed Up and Go Test (TUG_{single}) and dual-taksing TUG with a concurrent manual (TUG_{manual}) or cognitive ($TUG_{cognitive}$) task in the study group (N=7) based on a 1-week test-retest interval.

		mean±SD (s)	mean±SD (s) on retest	ICC (95% CI)	SEM	MDC_{95}
TUG_{single}	first trial	7.42 ± 1.66	7.40 ± 1.55	.987 (.925-.998)	0.20	0.56
	mean of first two trials	7.51 ± 1.60	7.41 ± 1.56	.994 (.969-.999)	0.17	0.48
	mean of three trials	7.54 ± 1.56	7.43 ± 1.57	.994 (.971-.999)	0.16	0.43
TUG_{manual}	first trial	8.14 ± 2.01	8.56 ± 2.02	.867 (.467-.975)	0.73	2.02
	mean of first two trials	8.29 ± 2.08	8.52 ± 2.03	.965 (.814-.994)	0.55	1.53
	mean of three trials	8.32 ± 2.19	8.51 ± 2.04	.973 (.854-.995)	0.51	1.41
$TUG_{cognitive}$	first trial	8.72 ± 1.28	8.73 ± 1.21	.989 (.936-.998)	0.14	0.39
	mean of first two trials	8.55 ± 1.25	8.61 ± 1.17	.994 (.969-.999)	0.14	0.37
	mean of three trials	8.52 ± 1.35	8.59 ± 1.24	.988 (.935-.998)	0.21	0.58

ICC: intraclass correlation coefficient; CI: confidence interval; SEM: standard error of measurement; MDC: minimal detectable change

Table 2. Pearson's correlation coefficients between TUG tests and the number of frailty and of falls (N=66 by using the mean of the first two trials).

	TUG_{single}	TUG_{manual}	$TUG_{cognitive}$
Number of frailty			
Correlation	0.288*	0.329*	0.180
partial correlation[a]	0.220	0.269*	0.062
Number of falls			
Correlation	0.272*	0.295*	0.222
partial correlation[a]	0.233	0.263*	0.150

[a]: controlled according to age
*: $P < 0.05$

Discussion

This study is the first to focus on community-dwelling middle-aged and older adults to determine (1) the retest reliability and MDC, (2) the optimal number of trials necessary for stable performance, and (3) construct validity in both single- and dual-tasking TUG tests. The results showed that two formal trials is the best number of trials for optimal retest reliability and MDC. By using the mean of the first two trials, ICC for TUG_{single}, TUG_{manual}, and $TUG_{cognitive}$ were 0.994, 0.965, and 0.994 respectively. MDC for TUG_{single}, TUG_{manual}, and $TUG_{cognitive}$ were 0.48, 1.53, and 0.37 seconds respectively. Construct validity was found only in TUG_{manual} with regard to its relationship with the degree of frailty and number of previous falls after controlling for age ($r = 0.269$ and 0.263 respectively).

The excellent retest reliability in this study is comparable to previous experiments on single-[2,15] and dual-taking TUG[22] in the community settings. The MDC value in this study is close to that reported for pre-manifest patients with Huntington disease (1.34 seconds)[18], and is much smaller compared to that reported for etiological populations such as patients with Huntington disease (2.98 seconds)[18], dementia (4.09-5.88 seconds)[16,17], and Parkinson disease (3.5-11 seconds)[19-21]. The MDC values for single- and dual-tasking TUG in community-dwelling middle-aged and older adults are therefore reasonable, and they provide clinicians important information that they can use to evaluate a patient's status before and after treatment. Although community-dwelling middle-aged and elderly people are relatively healthy, they nevertheless need health promotion and preventive interventions[30,31] in order to decrease the risk of frailty or falls[32] as well as further disability and adverse health outcomes[33].

The results in this study showed that two formal trials is the optimal number for a stable performance reading, which has been found previously by Dal Bello-Haas et al. who reported that the retest reliability in Parkinson disease could be improved from ICC 0.69 by using one trial data to ICC 0.76 by taking average of two trials[21]. The finding of an optimal trial number of two not only helps to increase retest reliability, compared to just one trial[2,8,19,21], but also saves time needed to perform, compared to three trials[10,22] which is especially important in large-scale community screening.

Previous studies have found single-tasking TUG to have construct validity with regard to its relationship with the Berg Balance Scale, gait speed, and Barthel Index[2]. The results of this study demonstrated that dual-taking TUG tests had construct validity with regard to its relationship with frailty and previous falls. Frailty and falls are two critical issues in middle-aged people who, when living with an inactive life style[30] or having midlife obesity[31], are at risk of developing frailty with aging. Unlike previous studies[4-7], this study did not find a significant relationship between single-tasking TUG and frailty or falls. Construct validity was found only in TUG_{manual}, which is in accord with a recent study showing better ROC and OR values for falls of TUG_{manual} task compared to TUG_{single} and $TUG_{cognitive}$ tasks[34].

This study limited in that it did not explicitly instruct the participants about task prioritization, in order to observe their natural strategy of dividing their attention. However, Oh-Park et al. have documented the effects of task prioritization and found that healthy older adults adopt the posture first strategy even when their attention is directed toward a secondary motor task while walking[35]. The current study was also limited in that it is based on a convenience sample. The convenience sample represented community-dwelling middle-

aged and older adults who were ambulatory and willing to participant in research and community-based activities. Thus, the results can only be generalized to adults who are similar to the study population. Nevertheless, the prevalence of prefrailty in this study, 57.6%, is close to the value (58.5%) reported in a study that was conducted on a larger representative sample in a northern Taiwan community using the same prefrailty criteria[26]. Finally, this study is limited in that retest reliability was derived on data from only seven participants. Further larger-scale studies are warranted.

In conclusion, this study examined the validity and reliability of single- and dual-tasking TUG tests in a group of community-dwelling middle-aged and elderly people in Taiwan who were ambulatory and actively participated in community-based activities and found that TUG_{manual} poses greater construct validity and high retest reliability, compared to TUG_{single} and $TUG_{cognitive}$. Conducting two trials and taking the average of TUG_{manual} can efficiently optimize its retest reliability (ICC 0.965) with MDC 1.53 seconds. However, because the results of this study were based on a small sample of middle-aged and elderly Taiwanese adults, further larger-scale studies are warranted. Our results can only be limited to middle-aged and elderly in Taiwan and those with a similar lifestyle in other Asia countries.

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Original Article

單任務與雙任務計時起走測試之信度與最小可偵測變化值

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目的：本研究旨在探討單雙任務計時起走測試之達成穩定表現所需測試數、再測信度、最小可偵測變化值（MDC）、以及建構效度。

方法與結果：本橫斷式研究收錄66位50歲以上之社區活躍中老年人。主要變項為執行單任務計時起走測試（TUG_{single}）、搭配一拿水杯任務之雙任務計時起走測試（TUG_{manual}）、搭配一連續減3任務之雙任務計時起走測試（$TUG_{cognitive}$）所需時間，每種任務在練習1次後皆測量3次。此外記錄受試者過去跌倒經驗，並測量衰弱指標。受試者中7位在1周後返回再測。根據這7位受試者（平均年齡69.5 ± 7.7歲）的資料，從第一次測量的單次資料到前兩次測試的平均，標準測量誤(SEM)和MDC顯著下降，尤其在TUG_{manual}特別明顯。使用三次測試的平均並沒有進一步大幅下降SEM和MDC，在$TUG_{cognitive}$反而增加了。使用前兩次測試的平均，再測信度（組內相關係數；ICC）和MDC分別為0.994-0.965和0.37-1.53秒。根據66位受試者（平均年齡71.6 ± 8.1歲）的資料，TUG_{single}和TUG_{manual}都和衰弱指標數和跌倒次數顯著相關，TUG_{manual}在控制年齡後的部分相關係數仍然維持顯著（部分相關係數分別為0.269和0.263）。

結論：和TUG_{single}以及$TUG_{cognitive}$相比，在社區中老年人中TUG_{manual}具有建構效度和絕佳再測信度。測量兩次之後取平均值可以最佳化TUG_{manual}的再測信度（ICC 0.965）和MDC（1.53秒）。然而，上述結果是根據於小樣本，未來還需要更多研究來加以測試。

關鍵詞：功能性活動能力、建構效度、信度、最小可偵測變化值、衰弱

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