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Reliability of clinically feasible dual-task tests: Expanded timed get up and go test as a motor task on young healthy individuals

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ABSTRACT

Dual-Task testing has been reported to have a higher sensitivity to deficits associated with concussion; however, the feasibility as a clinical or field test is questionable due to the requirements of laboratory-based equipment. With an overarching goal of exploration of clinically feasible Dual-Task testing options, the specific aims of this study were 1) to evaluate the reliability of Dual-Task testing methods using the Expanded Timed Get-Up-and-Go (ETGUG) paired with Backward Digit Recall (BDR), Serial Seven (SS), and Auditory Pure Switch Task (APST), and 2) to determine the effects of Dual-Task testing on motor and cognitive performance in healthy college-aged individuals. Fifty-four healthy young adults completed two separate testing sessions, which consisted of Single-Task tests in a randomized order followed by 3 pairs of Dual-Task tests in a randomized order. Test-retest reliability for ETGUG time to completion was excellent for all Single- and Dual-Task conditions (ICC 0.89–0.92); however, $ETGUG_{BDR}$ and $ETGUG_{SS}$ were associated with learning effects (p = 0.002 and 0.007, respectively). Test-retest reliability for Response Rate of the cognitive tasks was lower than those of motor task and all outcomes were associated with learning effects. The completion time of the $ETGUG_{APST}$ pair indicated excellent reliability with no learning effect. Performance level declined in all tasks under Dual-Task conditions compared to Single-Task; however, motor tasks showed larger deficits indicating the prioritization of the cognitive task compared to the motor task.

1. Introduction

Executive functioning allows higher-order cognitive behavior such as planning, monitoring, and executing a sequence of goal-oriented complex actions and is often affected by concussions [1]. Dual-Task testing is one method of assessing executive function, specifically assessing “divided attention” (attention necessary to multi-task) and is commonly used in older adults to predict fall risk [2]. Decreased executive function has been associated with altered gait performance in older adults when a cognitive task is performed simultaneously [3]. Dual-Task testing has also been reported to detect continued neurocognitive and functional deficits in a concussed athlete, even after standard concussion assessment scores returned to normal [4–9]. Assessment of executive function, specifically divided attention, may provide further insight regarding readiness for returning to play as sports participation involves simultaneous motor and neurocognitive function [10]. It has been suggested that Dual-Task testing has the potential to be a more sensitive and practical concussion assessment tool [11]. The National Athletic Trainers' Association position statement on concussions endorses the use of different types of screening tools that separately evaluate postural stability, neurocognitive function and self-reported symptoms, which has been shown to be sensitive, reliable, and feasible in a clinical setting [12]. Despite the growing evidence supporting the efficacy of Dual-Task testing for concussion assessment, testing protocols reported in previous studies typically require advanced laboratory equipment to measure exclusive outcomes such as center of mass and ellipse area during gait and balance activities [4–9,11,13–16] and are therefore impractical in clinical settings.

The Timed-Up-and-Go Test is an established clinical test used to assess gait and postural control [17]. Gait speed during the Timed-Up-and-Go test has been shown to decrease significantly in an elderly population when combined with a cognitive task [17]. Slower gait speed during Dual-Task tests using level-walking has also been reported in concussed individuals [4,7,9,16]. These studies suggest that changes in gait performance instigated by a concurrent cognitive task, referred to as Dual Task Cost (DTC), is measureable using gait speed. The Expanded-Timed-Get-Up-and-Go test (ETGUG) is a modification of the

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Timed-Up-and-Go test and is considered a more appropriate clinical assessment for physically active individuals [18]. The increase in walking distance from six to twenty meters provides an extended period of time for cognitive task performance when utilizing Dual-Task testing. The only equipment necessary to implement the ETGUG is a chair, timer, and 10-m walkway, which makes this test more feasible in a clinical setting compared to a laboratory-based gait assessment that requires motion analysis systems.

The ideal cognitive tasks to be paired with ETGUG should be easily administrable by a single examiner in a clinical setting. The selected cognitive tasks should not utilize the same input or output used for the motor task, which would cause structural interference. For example, reading a sign and catching a baseball both require visual input, which limits the ability of the Dual-Task test to assess divided attention [19]. Controlling for structural interference allows any deficiencies in Dual-Task performance, when compared to Single-Task performance, to be attributed to the overload of the participant's attention capacity. The Serial Sevens (SS) test and the Auditory Pure Switch Task (APST) test have previously been used in Dual-Task research and the Backward Digit Recall (BDR) test is commonly used in on-field concussion assessment [4,6,13]. These tasks do not create structural interference when paired with the ETGUG and are number-based in order to minimize the influence of the participants' English ability on the outcome measures as compared to word-based tasks. These are also auditory-based tests that a clinician could implement without having additional equipment, as opposed to visual-based test that requires a computer or projector.

Previous Dual-Task concussion research has predominantly focused on tasks requiring extensive equipment such as three-dimensional motion analysis system, Sensory Organization Test and computerized neurocognitive tests [4–9,11,13–16]. Therefore, the goal of this study was to identify a combination of motor and cognitive tasks that produced a reliable and clinically feasible Dual-Task test in healthy young adults that, once established, may prove valuable through future investigations in assessing deficits in concussed patients in clinical settings. Therefore, the specific aims of this study were 1) to evaluate the reliability of the Dual-Task testing methods using ETGUG paired with SS, APST, and BDR, and 2) to determine the effects of Dual-Task testing on motor and cognitive performance in healthy college-aged individuals.

2. Methods

2.1. Participants

A total of 54 participants (33 females, 21 males) were recruited from the university. (Table 1) Exclusionary criteria included: a history of diagnosed concussions, lower extremity injury within the last 3 months, diagnosed learning disability, previous exposure to SS, BDR, APST, or ETGUG, or any physical condition that could affect the outcomes of the test. Of the 54 participants, two males were unable to complete the testing sessions due to injury. All participants completed an informed consent form approved by the university's Human Studies Program Institutional Review Board.

Table 1
Participant demographics.

	Male (n = 21)	Female (n = 33)	Overall (n = 54)
Age (y/o)	20.90 ± 1.6	21.00 ± 1.7	20.98 ± 1.67
Height (m)	1.75 ± 0.10	1.65 ± 0.08	1.69 ± 0.10
Body Mass (kg)	75.87 ± 17.33	62.71 ± 14.45	67.83 ± 16.77

2.2. Dual-Task conditions

2.2.1. Motor task

Expanded Timed Get-Up-and-Go (ETGUG) was used as the motor task. Participants were instructed to be fully seated with their back against the back of an armless chair (seat height ~46 cm), stand once they heard a verbal cue, walk around a cone placed 10-m from the chair, and sit back down in the fully seated position. The measured outcome was the total time to complete the course. [18] The same examiner recorded the time to completion, started at the verbal cue and stopped when the participant had returned to fully seated position, using a digital hand-held stopwatch.

2.2.2. Cognitive task

Three different auditory-based cognitive tasks were paired with ETGUG: SS, APST, and BDR. Participants were given instructions, including an example, prior to each task. All cognitive tests were administered for 20 s during the Single-Task session to standardize the testing duration for all cognitive tasks. This duration was determined based on the pilot testing to estimate the approximate time required to complete the ETGUG. The measured outcomes for the cognitive tasks were Percent Accuracy and Response Rate. Percent Accuracy was defined as the ratio of correct answers to the total number of responses. Response Rate was defined as the ratio of total number of responses to completion time (either 20 s for the Single-Task sessions or ETGUG time to completion for the Dual-Task sessions).

- Serial Sevens (SS)

Participants were given a random number between 80 and 100 and instructed to recite subsequent numbers resulting from subtracting seven for each response throughout the test. Each subtraction was considered a response; when participants failed to perform a correct subtraction, an error was scored [20].

- Auditory Pure Switch Task (APST)

Participants were instructed to discriminate out loud between even and odd numbers as the examiner called them out. The number set was comprised of random digits between one and eight [6,13]. Each number was given to participants immediately following the previous response.

- Backward Digit Recall (BDR)

Participants were asked to repeat sets of numbers given by the examiner in reverse order. The numbers included in this task were one through nine. Each set of numbers was randomly selected with the following restrictions: no digits were present more than once in any set of numbers, immediate ascending or descending pairs were eliminated (e.g., 5–6 or 6-5), no double multiple jumps were included (e.g., 2–4-6 or 3–6-9), and no consecutive sequences began or ended with the same digit [21]. A baseline BDR trial was performed in accordance to the BDR procedure to determine the length of number sets used during Single-Task and Dual-Task trials. The baseline trials started from three digits and increased by one digit if the digits were repeated correctly until participants failed to respond correctly. The last set of numbers each participant repeated correctly was utilized as their number of digits used for Single-Task and Dual-Task trials [22]. Each set was counted as one response and considered correct only if the participant repeated all numbers correctly.

2.2.3. Dual-Task

The motor task was combined with a cognitive task to create three distinct Dual-Task conditions: $ETGUG_{BDR}$, $ETGUG_{SS}$, and $ETGUG_{APST}$. The measured outcomes of each component of the Dual-Task conditions were same as those measured in the Single-Task condition. To illustrate the effects of Dual-Task on motor and cognitive performance, DTCs were calculated as the ratio of the difference between Single- and Dual-Task to Single-Task [23].

2.3. Procedure

The data collection consisted of two sessions separated by an average of 18.0 ± 4.3 days in order to minimize learning effects [14,15]. Two experienced examiners administered all Single- and Dual-Task tests with the same examiner administering all tests for a given participant. Each participant performed two trials of each task and the mean of the trials was used for analysis. For the cognitive tasks, different numbers or sets of number were used for each trial and testing session. The ETGUG, SS, APST, and BDR were administered first in a randomized order as Single-Task tests to familiarize participants to each test, followed by three different pairs of Dual-Task tests in a randomized order; the same testing order was used for the second trial and the second data collection session for reliability analysis. All data collections were conducted in a quiet indoor facility with minimal distractions.

2.4. Statistical analysis

Data were analyzed using SPSS Statistical Analysis Software Version 23 (IBM, Armonk, New York, USA) with an alpha level of $p < 0.05$. The Percent Accuracy outcome was not normally distributed; therefore the median and inter-quartile ranges (IQR) were reported, and the Intra-class Correlation Coefficients (ICC), and Standard Error of the Mean (SEM) should be interpreted with caution. Test-retest reliability of outcome measures for each task were analyzed using two-way mixed Intra-class Correlation Coefficients ($ICC_{2,1}$). Paired *t*-tests for ETGUG and Response Rate, and Wilcoxon Signed Rank test for Percent Accuracy were used to assess systematic differences between testing sessions and between Single- and Dual-Task conditions and to assess differences in outcome measures between trials and between genders. One-way repeated measures ANOVAs with Bonferroni adjustment for Post-hoc analyses were used to analyze the differences between Single- and Dual-Task conditions for the ETGUG. Intra-class correlation coefficients were interpreted as follows: poor reliability ICC < 0.40, fair to good reliability 0.40 ≤ ICC < 0.75, and excellent reliability ICC ≥ 0.75 [24].

3. Results

Initial analyses revealed no significant differences between trials for all outcomes for both session 1 and session 2; therefore, two trials per condition was deemed adequate for comparing means of these trials for all outcome measures. Additionally, no differences were found between genders for any of the outcome variables and the data were combined by gender for subsequent analyses.

3.1. Test-retest reliability and differences between sessions

All ICC for ETGUG were excellent for both Single- and Dual-Task conditions. Completion time for $ETGUG_{BDR}$ and $ETGUG_{SS}$ significantly decreased during Session 2 compared to Session 1 (Table 2). The Response Rate for BDR and SS had excellent reliability for both Single- and Dual-Task conditions, while APST had fair to good reliability for both Single- and Dual-Task conditions; however, the Response Rate significantly increased during Session 2 compared to Session 1 in all testing conditions (Table 3). Percent Accuracy had fair to good reliability for all testing conditions; however, Percent Accuracy for BDR significantly increased during Session 2 compared to Session 1 for both Single- and Dual-Task conditions. There were no significant differences between testing sessions for SS and APST in both Single- and Dual-Task conditions (Table 3).

Table 2
Test-retest Reliability and Differences between Session 1 and Session 2 for Expanded Timed Get-Up-and-Go Completion Times (s).

	Test-retest reliability		Differences between Session 1 and Session 2	
	ICC	SEM (s)	Paired *t*-test *p* value	Mean Difference (s) (95% CI)
ETGUG	0.919	0.776	0.140	0.31 ± 1.48 (−0.10, 0.72)
$ETGUG_{BDR}$	0.914	1.609	0.002[a]	- 1.28 ± 2.88 (−2.08, −0.48)
$ETGUG_{SS}$	0.892	1.631	0.007[a]	- 1.15 ± 2.94 (−1.97, −0.33)
$ETGUG_{APST}$	0.920	1.156	0.927	0.03 ± 2.24 (−0.60, 0.65)

Abbreviations: ICC, Intra-class Correlation Coefficient, SEM, Standard Error of Mean, ETGUG, Expanded Timed Get-Up-and-Go; BDR, Backward Digit Recall; SS, Serial Sevens; APST, Auditory Pure Switch Task. Lack of subtext indicates single-task test.
Mean difference (95% CI) is displayed as Session 2 minus Session 1; negative value indicates improvement (faster walking) during Session 2.
[a] Significant difference between Session 1 and Session 2 ETGUG completion times ($p < 0.05$).

Table 3
Test-Retest Reliability and Differences between Session 1 and Session 2 for Response Rate and Percent Accuracy.

Response Rate				
	Test-retest reliability		Differences between Session 1 and Session 2	
	ICC	SEM (resp/s)	Paired *t*-test *p* value	Mean Difference (resp/s) (95% CI)
BDR	0.951	0.016	< 0.001[a]	0.02 ± 0.03 (0.01, 0.02)
BDR_{ETGUG}	0.957	0.014	0.024[a]	0.01 ± 0.03 (−0.01, 0.02)
SS	0.775	0.059	< 0.001[a]	0.07 ± 0.09 (0.04, 0.09)
SS_{ETGUG}	0.885	0.041	< 0.001[a]	0.04 ± 0.07 (0.02, 0.06)
APST	0.739	0.039	< 0.001[a]	0.04 ± 0.06 (0.01, 0.06)
$APST_{ETGUG}$	0.543	0.069	0.019[a]	0.04 ± 0.11 (0.03, 0.07)
Percent Accuracy				
	Test-retest reliability		Differences between Session 1 and Session 2	
	ICC	SEM (%)	WSR test *p* value	Median Difference (IQR)
BDR	0.647		0.000[a]	9.52 (20.00)
BDR_{ETGUG}	0.681		0.012[a]	9.52 (35.91)
SS	0.613		0.225	0.00 (17.31)
SS_{ETGUG}	0.681		0.665	0.00 (12.22)
APST	0.448		0.080	0.00 (0.00)
$APST_{ETGUG}$	0.651		0.779	0.00 (0.00)

Abbreviations: ICC, Intra-class Correlation Coefficient, SEM, Standard Error of Mean, resp/s, response per second, BDR, Backward Digit Recall; $ETGUG_{BDR}$, Dual-Task Backward Digit Recall with Expanded Timed-Get-Up-and-Go test, WSR, Wilcoxon Signed Rank test, IQR, interquartile range. Lack of subtext indicates single-task test.
Mean difference (95% CI) is displayed as Session 2 minus Session 1; positive value indicates improvement during Session 2.
[a] Significant difference between Session 1 and Session 2 ($p < 0.05$).

3.2. Differences between single − and dual-task

Completion times for the ETGUG significantly increased for all Dual-Task conditions when compared to Single-Task in both Sessions 1 and 2 (Table 4). In Session 1, Response Rate and Percent Accuracy for APST significantly decreased under Dual-Task conditions compared to Single-Task, while no significant differences existed between Single- and Dual-Task conditions for SS and BDR (Table 5). In Session 2, the Response Rates of all three cognitive tests significantly decreased during Dual-Task compared to Single-Task; no significant difference existed between Single- and Dual-Task conditions for Percent Accuracy in all cognitive tasks (Table 5). The DTC was consistently larger in the motor task (Time to Completion) compared to the cognitive tasks (Response Rate and

Table 4
Comparison of Expanded Timed Get-Up-and-Go Test Between Single-Task and Dual-Task.

	ST	DT-BDR	DT-SS	DT-APST
Session 1				
Mean ± SD (s)	19.96 ± 2.73	25.85 ± 6.22[a]	25.39 ± 5.60[a]	22.16 ± 4.57[a]
95% CI of mean difference (s) LB, UB		4.33, 7.75	3.98, 7.09	1.29, 3.16
Session 2				
Mean ± SD (s)	20.27 ± 2.72	24.57 ± 4.64[a]	24.24 ± 4.23[a]	22.19 ± 3.54[a]
95% CI of mean difference (s) LB, UB		3.15, 5.45	3.00, 4.95	1.28, 2.56

Abbreviations: DT-BDR, Expanded Timed Get-Up-and-Go paired with Backward Digit Recall; DT-SS, Expanded Timed Get-Up-and-Go paired with Serial Sevens; DT-APST, Expanded Timed Get-Up-and-Go paired with Auditory Pure Switch Task; 95%CI, 95% Confidence Interval of Mean Difference; LB, Lower Bound; UB, Upper Bound.
[a] Significant difference between Single- and Dual-Task conditions indicated by one-way repeated ANOVA($p < 0.001$).

Percent Accuracy) for all Dual-Task combinations (Table 6).

4. Discussion

4.1. Reliability

Test-retest reliability for Single-Task ETGUG completion time was excellent (ICC 0.92) in a young healthy population. No significant difference was found in Single-Task ETGUG completion time between testing sessions, indicating no significant practice effects for walking speed for both testing sessions. A change in walking speed during Dual-Task conditions can be attributed to the effect of attention overloading. Under Dual-Task conditions, test-retest reliability for ETGUG time to completion was excellent for all combinations (ICC 0.89 to 0.92); however, systematic differences were identified in ETGUG completion times when paired with BDR and SS, possibly due to a learning effect, as participants walked significantly faster during Session 2 (Table 2). This practice effect was not seen in the $ETGUG_{APST}$ pair.

For cognitive tasks, Percent Accuracy tends to have lower reliability compared to Response Rate, possibly due to the low between subject variability, or ceiling effect, especially for APST, as most participants answered with 100% accuracy. Our results agree with Plummer et al. [23] who reported poor reliability of the accuracy score and recommended the use of response rate as a measure for cognitive tasks. In our study, the Response Rate for all tests improved during Session 2 compared to Session 1 indicating possible learning effects (Table 3). The Response Rate allows trial-to-trial comparison by accounting for differences in participants' ETGUG completion time; however, it also makes interpretation more complicated. For example, one more response will result in a 0.046 (response/s) increase in Response Rate given an ETGUG walking time of 22 s, while one second faster completion time of ETGUG will result in a 0.022 (response/s) increase in Response Rate, given 10 responses. The learning effects seen in the Response Rate could be due to either a faster ETGUG completion time and/or increased number of responses; it is difficult to interpret the contribution from each component. To better understand the clinical meaningfulness of changes in Response Rate, assessment of completion time and total responses of each individual is necessary.

The completion time of $ETGUG_{APST}$ was the only Dual-Task outcome with excellent reliability and no learning effect. As reliability could be dependent on the participants' skill level, tasks that can be performed naturally and/or accurately are suggested for Dual-Task combinations [23]. Both ETGUG and APST meet this criterion, yet the Response Rate for APST was associated with a learning effect, suggesting that the ETGUG time to completion is the more reliable outcome measure for the Dual-Task test. Our findings are consistent with previous studies that reported excellent reliability on walking time or velocity and lower reliability on cognitive tasks using various populations [25–27]. Despite the excellent reliability for ETGUG completion time, systemic differences between sessions were indicated for the $ETGUG_{BDR}$ and $ETGUG_{SS}$ with more than one second improvement. As BDR and SS are more complex and novel tasks compared to APST, it is possible that these tasks produced more learning effects resulting in improvement of both ETGUG completion time and Response Rate. Conversely, APST is a simple cognitive task with limited area for improvement as most participants answered with 100% accuracy, resulting in consistent

Table 5
Comparison of Response Rate and Percent Accuracy Between Single- and Dual-Task Conditions.

Task		Response Rate			% Accuracy		
		Mean ± SD	*Paired t-test*	95% CI	Median, IQR	*WSR test*	95% CI
			p value	LB, UB		*p value*	LB, UB
Session 1							
BDR	ST	0.173 ± 0.071	1.000	−0.012, 0.012	73.21, 27.75	0.412	−8.919, 2.226
	DT	0.173 ± 0.064			73.86, 31.77		
SS	ST	0.293 ± 0.107	0.177	−0.035, 0.007	91.61, 19.06	0.548	−4.266, 2.530
	DT	0.279 ± 0.115			92.58, 16.67		
APST	ST	0.819 ± 0.069	0.024[a]	−0.065, −0.005	100.00, 0.00	0.027[a]	−0.517, −0.057
	DT	0.784 ± 0.122			100.00, 0.00		
Session 2							
BDR	ST	0.190 ± 0.077	0.024[a]	−0.016, −0.001	81.67, 28.64	0.118	−11.304, 1.202
	DT	0.181 ± 0.070			80.00, 29.93		
SS	ST	0.356 ± 0.138	0.003[a]	−0.063, −0.014	95.50, 9.92	0.180	−5.528, 0.942
	DT	0.318 ± 0.128			94.28, 15.39		
APST	ST	0.859 ± 0.084	< 0.001[a]	−0.054, −0.022	100.00, 0.00	0.779	−0.368, 0.358
	DT	0.820 ± 0.079			100.00, 0.00		

Abbreviations: BDR, Backward Digit Recall; SS, Serial Sevens; APST, Auditory Pure Switch Task; ST, Single −Task; DT, Dual-Task; 95%CI, 95% Confidence Interval of Mean Difference (Mean difference is displayed as DT minus ST); LB, Lower Bound; UB, Upper Bound, WSR, Wilcoxon Signed Rank test, IQR, Interquartile range.
[a] Significant difference between Single- and Dual-Task conditions ($p < 0.05$).

Table 6
Dual Task Cost for Motor and Cognitive Outcome Measures for Both Session 1 and Session 2.

ETGUG paired with:	Session 1			Session 2		
	BDR	SS	APST	BDR	SS	APST
Time to Completion (%)	−29.40 ± 20.01	−27.26 ± 19.22	−10.61 ± 11.49	−21.01 ± 14.48	−19.52 ± 12.28	−9.40 ± 8.68
Response Rate (%)	2.64 ± 18.34	−1.85 ± 33.29	−4.13 ± 12.70	−2.56 ± 15.5	−8.26 ± 24.14	4.19 ± 6.78
Percent Accuracy (%)	−4.71 ± 39.51	−0.92 ± 18.75	−0.29 ± 0.84	−5.66 ± 33.34	−0.01 ± 22.00	0.00 ± 1.32

Dual Task Cost calculated as ((Dual Task Outcome-Single Task Outcome)/Single Task Outcome)*100% for Response Rate and Percent Accuracy and as − ((Dual Task Outcome-Single Task Outcome)/Single Task Outcome)*100% for ETGUG as described by Plummer and Eskes [30].

attention allocation between motor and cognitive tasks.

4.2. Effects of dual-task

The ETGUG results revealed significant and consistent deficits in performance, indicated by increased completion time, during Dual-Task conditions. Participants walked more slowly when performing any cognitive tasks simultaneously, compared to Single-Task ETGUG. Furthermore, $ETGUG_{BDR}$ and $ETGUG_{SS}$ resulted in larger DTC, over twice the size of $ETGUG_{APST}$, indicating larger discrepancies in completion time between Single- and Dual-Task conditions. This indicates less attention was allocated to the walking task during $ETGUG_{BDR}$ and $ETGUG_{SS}$ due to higher attention demands for more complex cognitive tasks resulting in slower completion time, as compared to those of $ETGUG_{APST}$. The increase in completion times for all ETGUG combinations ranged from 1.28 to 7.75 s, which are detectable in the clinical setting by a hand-held stopwatch. Our results agreed with previous findings of decreased walking speed during Dual-Task condition, as well as when Dual-Task was performed with more complex cognitive tasks. [5,28] Both studies utilized gait velocity (m/sec) as an outcome measure recorded by the laboratory-based gait analysis system; our study provides evidence that gait velocity changes owing to Dual-Task tests are also detectable using clinically feasible methods.

Decreases in cognitive task performance under Dual-Task condition were also indicated; however, these deficits were smaller compared to those of ETGUG completion time indicated by the smaller DTC (Table 6). Plummer and Eskes [23] discussed the importance of assessing DTC for both cognitive and motor outcomes to address possible difference in prioritization of the task [23]. For example, prioritization of the cognitive task allows more attention allocation resulting in a smaller DTC for the cognitive task; consequently less attention is allocated for the motor task resulting in a larger DTC. Lower DTC for cognitive tasks seen in our study indicates participants were prioritizing the cognitive task at the expense of the motor task. The increased ETGUG completion time is most likely associated with slower walking speed, which suggests the adaptation of “safe” strategies to avoid the risk of falling [29].

One limitation of this study was a lack of task priority standardization, as our participants were not instructed on which task to prioritize. Standardization of task priority is reported to improve reliability [23], which may also allow more reliable trial-to-trial comparisons.

In conclusion, our study indicated time to completion of the $ETGUG_{APST}$ was the most reliable outcome measure for assessing Dual-Task function in healthy young adults. While these results do not indicate how acutely concussed individuals might respond to similar Dual-Task testing, the establishment of a clinically feasible, reliable Dual-Task test in healthy young adults provides a valuable tool for subsequent research on concussed patients. Given its viability as an easily implementable clinical Dual-Task test, the sensitivity and specificity of this test on concussed individuals warrants further investigation.

Conflicts of interest statement

There are no conflicts of interest for any of the authors.

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