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ORIGINAL PAPER

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# The Role of Dual Tasking in the Assessment of Gait, Cognition and Community Reintegration of Veterans with Mild Traumatic Brain Injury

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## ABSTRACT

**Background:** This study focussed on the effect of dual versus single tasking on balance, gait and cognition in veterans with mild traumatic brain injury (mTBI). We examined the correlation between these parameters, with responses to questions on community reintegration activities. **Method:** 22 male and female veterans (aged 19-65) walked along a narrow and 6.1-meter long path, both at their self-selected and fastest but safe pace under single and dual tasking conditions. For dual tasking, participants were required to recall and vocalize a 5-digit number at the end of the path. The outcome measures were the accuracy, velocity, cadence, stride length, and number of steps off the path. We calculated the reliability and correlation coefficient values for the walking time compared with the stride length, velocity, and percentage of swing and stance. **Results:** Under dual task, the participants demonstrated slower gait, recalled shorter digit span and stepped off the path 12.6% more often than under single task. The stride length decreased by about 20% and the stride velocity increased by over 2% in dual compared with single tasking. **Conclusions:** Dual tasking slows down the gait and reduces the attention span in patients with mTBI, which can negatively impact their community reintegration, at least early after their hospital discharge, hence the need for exercising caution with their community reintegration activities. Dual tasking may have the potential to improve balance, gait and attention span of the patients in the long-term, thus leading to safer community integration, if incorporated in the rehabilitation plans.

**Keywords:** Mild traumatic brain injury, single and dual tasking, functional gait assessment, cognition, community reintegration, U.S. veterans.

## 1. INTRODUCTION

It is estimated that more than 220,000 veterans in the United States have sustained traumatic brain injuries in military operations in Iraq and Afghanistan wars. Approximately, 10-20% of these individuals suffer from mild traumatic brain injury (mTBI) and present with impairments that make their community reintegration and return to work difficult, if not impossible (1, 2, 3). Although veterans are routinely evaluated by the Veterans Affairs (VA) healthcare system, they may not be diagnosed with mTBI for months or years after sustaining battle field traumas. This condition can compromise balance, gait and dual task performance, and pose other long-term challenges, such as subtle pain, headaches, hyper- or hypsomnia, dizziness, and mild cognitive dysfunction for the veterans (3, 4). Equally importantly, these symptoms can make the rehabilitation of the veterans challenging for the physical therapist while posing difficulties toward their community reintegration (4, 5).

The brain's ability to organize multi-task interactions is the essential component of motor control and balance (6, 7). Dual tasking, i.e., the concurrent performance of a *motor-motor* or *motor-cognitive* task is performed independently and is tested by measuring the interference of one or both tasks in one another (7, 8). Maintaining balance during dual or multi-tasking is a complex outcome of trunk stability and the sensory-motor and/or automatic central functions (6, 7). Therefore, performing two tasks simultaneously demands a higher degree of attention, balancing skills and executive function than does a single task performance (7). Obviously, poor attention and cognitive skills result in impaired motor-

motor or motor-sensory tasks, such as maintaining static or dynamic balance. Further, repetitive voluntary movements result from complex central processes that lead to the development of motor skills (6).

Cortical field hypothesis (9) suggests that two different brain tasks that make use of the same cortical field cannot be performed simultaneously and a large population of neurons involved in a particular processing may not be available to contribute to dual tasking. A number of neuro-imaging studies have found that the activation of prefrontal, right inferior frontal and parietal cortex are related to dual tasking (10, 11, 12, 13). A recent study has demonstrated a correlation between visual-spatial tasks and increased gamma activity in the parietal lobe (14). During the processing of dual tasks by the brain, the cortical involvement rises as the tasks become more complex (15). In this context, the ability to process complex information is challenging even in healthy persons and becomes more limited in patients with traumatic brain injuries (16, 17). The brain balances demands by placing more emphasis on tasks that are most relevant (16). Also, the reaction time is significantly longer when performing visual or somato-sensory dual tasks than that required for a single task (18). The functional delay is referred to as dual task interference.

Impairments in executive function and attention have been detected under dual task condition in a case of brain injury, being associated with unsteady walking and stair climbing, and poor balance (8). Signs of impaired balance can also be reliable predictors of adverse outcomes in community integration and falls (19, 20, 21). However, detection of all long-term consequences of brain injury may take months or even years after the traumatic event (22). Therefore, it is essential to perform a thorough assessment of physical, cognitive, and psychosocial impairments of patients with mTBI, if a successful community reintegration is expected (22). Further, there is evidence to suggest that dual task interventions can improve walking speed and balance in patients with stroke or neurodegenerative diseases (19). Also, dual tasking can be applied to the clinical management of patients with mTBI by simulating real life and community integration activities (19, 20).

The purpose of this study was twofold: *a*) to investigate detectable changes in balance and gait in veterans with mTBI under single vs. dual tasking and, *b*) to develop an evidence-based assessment protocol to predict the quality of their functional balance as it relates to community reintegration. In this context, we compared balance and gait under single and dual task conditions, using objective motor-cognitive tests relevant to community reintegration (17). This approach has the potential to predict the recovery in balance and gait while facilitating safe community reintegration. The study findings could positively guide the initial clinical assessment and the follow-up of young and middle aged veterans alike.

## 2. METHODS

**Objective:** The objective of this study was to assess the relationship between gait disturbance and community reintegration responses in a population of veterans with mTBI, under single and dual task conditions.

**Study Design:** The study design consisted of five parts: *a*) subject recruitment, *b*) screening tests, *c*) experimental

tests of gait parameters, *d*) collecting patients' responses to an established questionnaire on community integration, and *e*) statistically analyzing the outcome measures representing the patients' gait cadence, sway, the times spent for the swing, step, stride, stance, and for single or double limb support under single vs dual task conditions.

The researchers who conducted the tests were doctors of physical therapy (AL & DM) in their fellowship program at Washington DCVA Medical Center, each with over 20 years of clinical and research experience. A biostatistician (DM) analyzed the data for single versus dual tasking and balance, and examined the relationship of the participants' responses to an established questionnaire, focused on community reintegration activities and needs.

**Participants:** After obtaining the approval from the DC-VA's institutional review board (IRB), 26 eligible patients were initially referred to the study by their respective physicians from the Poly-trauma/TBI Clinic, Physical Medicine and Rehabilitation Service at DC Veterans Affairs (DC-VA) Medical Center, Washington, DC. However, four of them dropped out at some point and were, therefore, excluded from the study. The remaining 22 veterans were 16 male (72.7%) and 6 female (27.3%) 19 to 65 years old (average 45.4 y) had been diagnosed with mTBI. These veterans had previously sustained mild head traumas in the Iraq, Afghanistan and Vietnam Wars. The patients' consent and health information portability and accountability act (HIPAA) forms were obtained according to DC-VA policy, procedures and practices. The comprehensive evaluation electronic template was reviewed following IRB approval and HIPAA-compliant data collection procedures. The mTBI diagnosis for each patient was further confirmed by a careful review of patient's chart and the respective physician's clinical notes.

**Inclusion & Exclusion Criteria:** The study's main requirement was the patients' ability to walk for 50 meters in the community without assistance and attained a score of  $\geq 15/30$  on functional gait assessment (FGA) with or without using an assistive device. Also, they were screened on the military acute concussion evaluation (MACE) test and needed a score  $\geq 23/30$  to be included in the study. This test was used to ensure that the patients understood the study protocol and participated voluntarily (23, 24). Participants with a past medical history of peripheral neuropathy, CVA, Parkinsonian syndromes, multiple sclerosis, significant dizziness, bipolar, schizophrenia, seizure, psychiatric illnesses, significant visual or hearing disorders were excluded. In addition, patients with an amputation or orthopedic condition in the lower extremities, impaired ambulation, or acute hospitalization within the past three months were excluded from the study.

### Other Screening Tests:

**i. Balance Confidence:** Activities-specific Balance Confidence (ABC) test was used to screen the patients' confidence with various ambulation activities (25, 26).

**ii. Dizziness Handicap Index (DHI):** we used DHI, a 25-item self-assessment tool, to screen the self-perceived handicapping effects caused by dizziness (5, 27). Patients with a significant degree of dizziness were excluded.

**iii. Executive Function:** We used Frontal Systems Behavior (FrSBe) scale to screen the participants' executive function, including cognition (28, 29). This 46-item, self-reported set of scales quantify issues arising from impaired cognition,

disinhibition and apathy caused by damage to the brain’s frontal lobe. The operational definition of executive dysfunction is based on the clinical diagnosis made by a physician or by the patient’s responses to a series of standardized FrSBe questions. If the total score or any of the 3 subscale scores was below one standard deviation of the normative scale, the patient would qualify for impaired executive function.

**Experimental Tests:**

**Functional Gait Assessment (FGA):** For experimental test, we used a 10-item gait tool to objectively assess the patients’ functional gait (6). The outcome measure was the data averaged for three trials. The walk path was 6.1 meters long and 19 centimeters wide, as illustrated in Figure 1 (4). The accuracy and timing of the walk down the path for each patient were determined based on the number of steps kept within the boundary of the path and the length of time in seconds they took to complete the walk.

**Instrumentation:** The walking speed, gait and balance were examined separately through wearable BioSensics™ electrodes attached to the patients’ shins (30). Two electrodes were placed on the shins, three inches above the lateral malleoli, to record the time taken for the cadence, swing, step, stride, stance, sway, and single or double limb stance phases. The sensors transmitted signals to a computer, where the trajectories of the ankle and hip angles were estimated in an anteroposterior plane (31).

The FGA test consisted of the two components:

**i. Single Task:** Patients walked the path at a self-selected speed. This test had no cognitive component. See Figure 1 for the test layout under both single and dual tasking.

**ii. Dual Task:** Patients’ walked the path at a self-selected speed and were required to remember a set of 5-digit numbers and to report them at the end of the path. This test was performed according to *Walking and Remembering Test* as established by McCulloch et al. (4). We used the Wechsler adult intelligence scale (digit recall test) for dual tasking only (32), with the outcome measure being the number of digits reported correctly to the testers at the end of the walk (Figure 1).

**Community Reintegration Score (CRIS)** was used to determine the correlation between the veterans’ responses to established questions related to physical and emotional functions required for community reintegration after military deployment (33).

**Statistical Analysis:** We used SPSS software version 22 to perform the statistical analysis and to calculate the means on the following gait components: *i)* number of steps off path, *ii)* cadence velocity and *iii)* stride length under single and dual task conditions. We also calculated the percentage of change for the components of gait and analyzed the correlation between gait parameters and community reintegration scores.

**3. RESULTS**

Of the initial 26 eligible patients with mTBI, 4 dropped out and 22 completed all of the study components. These patients had sustained mild head traumas in the Iraq, Afghanistan and Vietnam Wars. The characteristics of the participants are presented in Table 1. Upon detailed initial screenings, all of the participants demonstrated residual deficits in balance, and gait performance, and showed some degrees of cognitive impairment.

Subject #	Gender (m/f)	Age (year)	Weight (Lb)	Height (ft., inch)
1	m	46	200	5'10"
2	m	43	231	5'7"
3	f	50	155	5'9"
4	m	39	254	5' 9"
5	m	44	220	5'7"
6	m	37	250	5'7"
7	f	45	137	5'5"
8	m	48	185	5'7"
9	m	57	180	6'2"
10	m	33	220	5'11"
11	m	65	235	6'0"
12	m	41	160	5'7"
13	m	48	185	5'7"
14	m	34	170	5'9"
15	m	59	151	5'5"
16	m	33	230	6'0 "
17	m	45	130	5'2"
18	m	60	155	5'0"
19	m	47	155	5'8"
20	m	65	235	5'11"
21	m	19	170	5'7"
22	m	40	170	5'7"
Average	m=16; f=6	45.4	189.9	5'6"

Table 1. Participants’ Characteristics

Gait Parameter	Walk Test		Percent Change (for dual task)
	Single Task (SD)	Dual Task (SD)	
Time to Walk the Path [sec]	7.68 (3.66)	6.94 (2.12)	- 9.64
Net Speed [meter/sec]	0.97 (31)	0.99 (0.30)	+1.02
Number of Time off Path	2.38 (2.04)	2.68 (1.93)	+ 12.60
Number of Steps per Path	8.50 (4.27)	10.22 (1.95)	+20.23
Cadence [steps/min]	91.80 (18.11)	93.85 (13.67)	+2.23
Stride Velocity [meter/sec]	0.97 (0.30)	1.00 (0.30)	+3.09
Stride Time [sec]	1.38 (0.36)	1.37 (0.36)	- 0.72
Stride Length [meter]	1.25 (0.20)	1.24 (0.26)	- 0.80

Table 2. Mean gait parameters under single and dual task conditions. SD = Standard deviation. Walking and Remembering test performed on a 6.1-meter long and 19-cm wide path (McCulloch, et al. 2009; Carlozzi et al. 2015).

**Functional Gait Vs Single and Dual Tasking:** The results demonstrated that the veterans had a slower gait and remembered shorter digit span while engaged in dual tasking, as compared with single tasking. Table 2 demonstrates the differences between the averaged gait parameters during the walking and remembering test (4), under single and dual task conditions. Under dual tasking, the participants stepped off the walking path 12.6% more often than they did under single tasking condition. Also under dual tasking, the participants’ walking cadence and velocity increased by over two percent. More significantly, the subjects’ stride length

Community Reintegration*	Executive Function**		
	Cognition	Apathy	Disinhibition
Extent of Participation CC (p-value)	- 0.470 (0.028)	- 0.345 (0.116)	- 0.217 (0.331)
Perceived Limitations CC (p-value)	- 0.580 (0.005)	- 0.298 (0.177)	- 0.222 (0.320)
Satisfaction CC (p-value)	- 0.495 (0.019)	- 0.334 (0.129)	- 0.334 (0.128)

Table 3. Correlation of community reintegration with executive function. \* Based on CRIS scores; \*\* Based on FrSBe scores. Numbers represent Pearson correlation coefficients (CC). Numbers in brackets denote p-values.

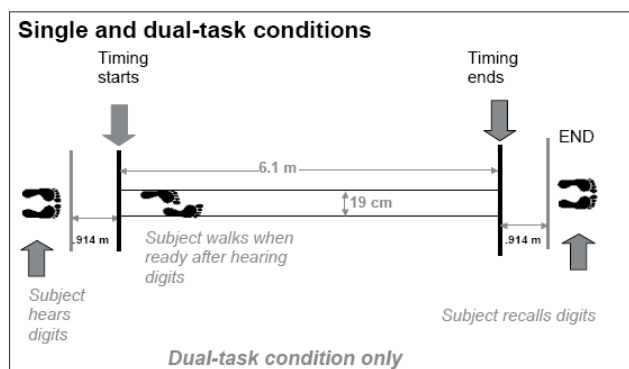


Figure 1. Study of gait parameters under single and dual tasking conditions. \*Figure 1, courtesy of McCulloch, et al. (2009).

decreased by slightly more than 20% while being mentally engaged in remembering numbers, i.e., double tasking, as compared with the same parameter measured for the walk alone (single tasking).

**Executive Function Vs Community Reintegration:**

The “cognition” component of executive function correlated moderately but significantly with the scores for the patients’ responses to questions on community reintegration. However, the scores for “apathy” and “disinhibition” did not correlate significantly with those for community reintegration (Table 3). The correlations of the components of executive function with the three subsets of community reintegration were consistently negative, regardless of the statistical significance.

**Statistical Analyses:**

Upon performing a 2-tailed non-parametric Pearson correlation analysis, there were significant correlation between the components of dual tasking and the scores representing community reintegration of the participants (p<.01). Also, upon a similar statistical treatment, dual tasking data correlated significantly with both DHI and ABC scores (p<.01 and <.05).

**4. DISCUSSION**

Ordinarily, humans use dual tasking in their day-to-day activities. We frequently walk while performing one or more cognitive or motor tasks, such as walking while carrying objects or conversing with others as we cross street and/or observe the traffic. American veterans with mTBI experience deterioration on gait during cognitive-motor or motor-motor dual task which then limits their quality of life, and increase risk of falls. They often report having problem with their gait during day-to-day activities. Obviously, this can increase their

risk of falls and deteriorate their quality of life. Based on the study findings, we can predict that improving upon balance and gait while engaged in dual tasking intervention should be an important focus in the rehabilitation of veterans with mTBI, aimed at enhancing the veterans’ community reintegration skills and their quality of life.

Ample evidence have been produced by previous studies in the elderly and patients with stroke or neurodegenerative diseases, suggesting that dual task training improves walking speed and balance (7, 20, 21, 34, 35). Although few randomized controlled trials with small sample sizes have been conducted in veterans with mTBI, none of them has addressed the effect of dual tasking on the community integration skills (36-38).

**Gait Vs Single and Dual Tasking:**

The objective of this study was to assess gait components under single versus dual task conditions in a population of American veterans with mTBI. We tested the hypothesis that dual tasking may negatively impact the participants’ gait pattern, which in turn may adversely influence the community reintegration activities of veterans with mTBI. Our outcome measures provide objective data on how gait training under single versus dual task may impact functional ambulation differentially. We found that dual tasking significantly slows down the gait in the veterans with mTBI and reduces their attention span due likely to the increased demand on the cognition. This may adversely impact the community reintegration of these patients, at least early after being discharged from the hospital. This finding calls for exercising caution regarding the patients’ community reintegration activities.

**Executive Function Vs Community Reintegration:**

Support for the significance of examining the patient’s cognitive function during the initial clinical assessment of patients with mTBI was demonstrated by the negative correlation of “cognition” during the screening process with the three subsets of community reintegration (Table 3). However, the “apathy” and “disinhibition” did not correlate significantly with the data on patients’ community reintegration activities.

Our assessment protocol may be applied to follow up the recovery rate of patients with mTBI at regular intervals, as they go through the rehabilitation process, and monitor the differential effect of individual physical and cognitive exercises performed by patients during dual or multi-task interventions. The protocol may also be used to monitor the progress patients make in their various community integration activities. Further, the protocol has the potential to raise the functional balance and cognitive demands placed on the patient to a higher level in today’s complex community interactions. Also, similar protocols may be used to monitor the short-term and long-term effects of dual and multi-tasking interventions used in patients with other neurological diagnoses. Such innovative approaches are likely to enhance the community integration activities of patients and ultimately the quality of their lives. Ample support for our suggestion to incorporate dual tasking in the rehabilitation of patients with mTBI comes from previous studies in patients with stroke or neurodegenerative diseases who had poor balance, slow gait and cognitive dysfunctions (7, 20, 21, 34, 35) similar to those we found in US veterans with mTBI.

Future advancements in the rehabilitation of veterans with mTBI could be made by developing interdisciplinary

approaches, based on the inclusion of dual or multi-tasking in the clinical interventions. In addition, clinicians and researchers are encouraged to explore the differential effects of concurrent dual and multi-tasking activities, at physical, cognitive, and psychosocial levels, in raising the efficiency of the clinical approaches to the management of veterans with mTBI or with other neurological conditions.

**Limitation of Study:** Although this study is a first step toward providing a new clinical assessment strategy in veterans with mTBI, the results may not be generalized to other neurological diagnoses and larger populations. We recommend using our study protocol in future randomized clinical trials (RCTs) to study larger patient populations with mTBI and other neurological conditions. Also, this study suggested significant differences in assessment outcome data for single versus dual task condition. Future RCTs are warranted in larger patient populations and at multiple clinical sites to establish whether the difference will prove to be clinically significant. Lastly, our results did not provide intervention strategies for veterans with mTBI, since they were beyond the scope of this study. Future studies based on our assessment protocol should be developed to provide treatment strategies, and to further explore the impact of dual tasking to improve upon patients community reintegration skills.

## 5. CONCLUSIONS

Dual tasking significantly slows down the gait and reduces the attention span of patients with mTBI, due likely to the increased demand on the cognitive function. This can adversely influence the community reintegration of the patients, at least early after discharge from the hospital; hence the need for exercising cautions as to the patients' community reintegration activities. The patients' scores on questions about their community reintegration concerns correlated moderately but significantly with those for the "cognition" but not with "apathy" and "disinhibition" components of executive function.

Our study protocol provides objective data and new outcome measures for the clinical assessment of patients with mTBI and other neurological conditions. It is likely that dual tasking may lead to greater improvement of balance and gait in the long-term while enhancing cognition through repeated mental exercises. This study is our first step toward developing a new method to incorporate data from functional balance, gait and cognitive exercise into the clinical assessment of patients with mTBI. This protocol may also be used to monitor the recovery rate of patients and the quality of life at regular intervals, as they make progress through the rehabilitation programs.

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- **Authors' Contributions:** Dr. Leland and Dr. Scholten conceived, designed the study and selected the tests. Dr. Scholten coordinated the patient recruitment and supervised the study. Dr. Leland and Ms. Mathis conducted the study, performed the tests, and compiled the data and test scores. Dr. Leland wrote the first draft of the paper and Mr. Maron and Mr. Kaveh B. Kelarestaghi recommended the statistical models and performed the correlation and regression analyses. Dr. Bakhshi and Dr. Tavakol wrote the drafts of the manuscript, and revised the final version of the paper for submission.

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