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Physical Performance and Fall Risk in Persons With Traumatic Brain Injury

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Abstract

Injuries sustained from traumatic brain injury (TBI) culminate in both cognitive and neuromuscular deficits. Patients often progress to higher functioning on the Rancho continuum even while mobility deficits persist. Although prior studies have examined physical performance among persons with chronic symptoms of TBI, less is known about the relatively acute phase of TBI as patients prepare for rehabilitation discharge. The aims of this cross-sectional study were to (a) compare balance and gait performance in 20 ambulant persons with moderate to severe TBI who were nearing rehabilitation discharge with their age-matched controls and (b) describe performance with thresholds for fall risk and community navigation. During a designed task circuit, 40 participants (20 persons with TBI and 20 controls) performed the Timed Up and Go (TUG), gait vel-ocity, and Walking and Remembering tests. Balance testing included the Fullerton Advanced Balance Scale (FABS) and instrumented Modified Clinical Test for Sensory Interaction in Balance (MCTSIB). Statistical analyses included analysis of covariance for group comparisons and a multivariate analysis of covariance for MCTSIB sway velocities with anthropometric controls. The TBI group (mean [M] age = 42, standard deviation [SD] =19.5 years; 70% males) performed significantly more poorly on all mobility tests ($p < .05$) and their scores reflected a potential fall risk. Gait velocity was significantly slower for the TBI versus control group (M = .96, SD = 2.6 vs. M = 1.5, SD = 2.2 m/s; $p < .001$), including TUG times (M = 13.5, SD = 4.9 vs. M = 7.7, SD = 1.4; $p < .001$). TBI participants also demonstrated significantly greater sway velocity on all MCTSIB condi-tions ($p < .01$) and lower performance on the FABS ($p < .001$). Performance indices indicate potential fall risk and community navigation compromise for

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individuals with moderate to severe TBI. Physical performance scores support the need for continued interventions to optimize functional mobility upon discharge.

Keywords

traumatic brain injury; gait; balance; falls; posturography

Introduction

Traumatic brain injury (TBI) is a major cause of morbidity, hospitalization, and disability in the United States (Center for Disease Control and Prevention, 2018). Operationalized as an alteration in function produced by an external force, TBI may be caused by motor vehicle accidents, acts of violence, and unintentional blunt trauma (Center for Disease Control and Prevention, 2018; Salottolo et al., 2017). In 2010, over two million emergency room visits were linked to TBI-related incidents (Center for Disease Control and Prevention, 2018). Mortality is highest for men and persons older than 65 years. Secondary injuries include hematomas and skull fractures and can require neurosurgical intervention (Sweeney, Salles, Harris, Spain, & Staudenmayer, 2015). Other complications such as cerebral hypoperfusion and hypothermia are associated with poorer outcomes (Jeremitsky, Omert, Dunham, Protetch, & Rodriguez, 2003). Persons with injuries involving hemispheric midline shift larger than five millimeters are more likely to require assistance in ambulation and selected activities of daily living at rehabili-tation discharge (Englander, Cifu, Wright, & Black, 2003).

Injury sequelae span from coma emergence to purposeful appropriate cogni-tion and are outlined in the Rancho Los Amigos Levels of Cognitive Function (Hagen, Malkmus, & Durham, 1979). Individuals recovering from injury present with a variety of cognitive and neuromotor deficits, including memory loss, dizziness, gait deviations, and balance dysfunction (Campbell & Parry, 2005). Secondary impairments extend to endurance and cardiovascular reserve com-promise; moreover, other complications such as heterotopic ossificans and con-tractures can protract functional recovery (Johns, Cifu, Keyser-Marcus, Jolles, & Fratkin, 1999; Mossberg, Amonette, & Masel, 2010; Singer, Jegosothy, Singer, Allison, & Dunne, 2002). Cognitive limitations and more severe injuries further impede subsequent return to employment and recreation (Andelic, Stevens, Sigurdardottir, Arango-Lasprilla, & Roe, 2012). Individuals who progress to the latter pole of the Rancho spectrum are often designated as higher functioning, given their appropriate automatic or purposeful cognition, though considerable mobility limitations can persist.

Gait deficits following TBI are common and are associated with limited community reintegration (Perry, Woolard, & Little, 2014; G. Williams, Galna, Morris, & Olver, 2010). Ambulation restrictions can obstruct effective home and community navigation. Individuals demonstrate step asymmetry, delayed dual task pro-cessing, and slower obstacle negotiation (Drijkoningen, Caeyenberghs, et al., 2015; McFadyen, Swaine, Dumas, & Durand, 2003; Valleé et al., 2006). Temporal changes include a slower gait velocity in both children and adults fol-lowing TBI (Katz-Leurer, Rotem, Keren, & Meyer, 2011; G. Williams, Morris, Schache, & McCrory, 2009). Pelvic abnormalities and a prolonged flexed knee posture during stance loading are common kinematic deviations (G. Williams et al., 2009). Locomotion recovery may take several months secondary to injury severity and lower extremity fractures (Watson & Hitchcock, 2004).

Impaired balance modulation includes increased sway with altered sensory environments and skewed center of mass trajectories (Kaufman, Chou, Rabatin, Brown, & Basford, 2006). Instability in the medial-lateral plane is particularly evident (Chou, Kaufman, Walker-Rabatin, Brey, & Basford, 2004). Balance deficits are associated with white matter deterioration, and mediators of stand-ing balance include age, injury severity, and posttraumatic amnesia (Drijkoningen, Leunissen, et al., 2015; Greenwald et al., 2001). Newton (1995) reported that persons with moderate to severe head injury demonstrated longer latencies and both symmetrical and asymmetrical balance responses following unexpected linear perturbation. Proposed causes of postural instability follow-ing TBI reflect central and peripheral vestibular involvement, including injury to cranial nerve eight as it traverses the auditory meatus (Guskiewicz, 2003). Dizziness and related disequilibrium can also ensue, secondary to symptomatic benign paroxysmal positional vertigo (Basford et al., 2003; Guskiewicz, 2003).

Falls are a common mechanism of TBI among older adults, with more severe injuries sustained from a sideways or backward fall (Hwang, Cheng, Chien, Yu, & Lin, 2015). Falls can occur because of pathology-related intrinsic causes or environmental factors. Following a TBI, individuals may be at considerably greater risk because of seizures, fatigue, cognitive deficits, and substance abuse (Kolakowsky-Hayner, Bellon, & Yank, 2016). Balance, gait, and coordination deficits further potentiate fall risk. Unintentional falls can occur during the in-patient hospital stay or after discharge.

Instrumented and observational tests have been used to examine physical performance and fall risk in rehabilitation. Gait velocity is a frequent assessment and a predictive gauge for frailty, fall risk, and mortality (Chainani et al., 2016; Odasso-Montero et al., 2005; Rothman, Leo-Summers, & Gill, 2008). Computerized gait mats and timed clinical measures with premeasured distances are employed to track functional recovery from brain injury (G. P. Williams, Robertson, Greenwood, Goldie, & Morris, 2005). Balance reaction has been assessed using forceplates and clinical tests that employ foam, a yardstick, and other tools (Lei-Rivera, Sutera, Galatioto, Hujsak, & Gurley, 2013). Posturographic analyses partitioning somatosensory, visual, and vestibular con-tributions to postural stability include the Sensory Organization Test and Modified Clinical Test for Sensory Interaction in Balance (MCTSIB; Navalon et al., 2014; Pickett, Radfar-Baublitz, McDonald, Walker, & Cifu, 2007).

Although considerable research has depicted the mobility profile of individ-uals with TBI in more chronic stages following their injury, fewer studies have addressed the acute rehabilitation phase. Similarly, little is known about the extent of fall risk given emergent deficits following injury. The aims of this study were to (a) compare gait and balance ability in ambulant individuals with TBI nearing the end of their in-patient rehabilitation stay with age-matched controls using forceplate and standard clinical measures and (b) describe the functional implications of TBI patients' physical performance scores, including fall risk and accepted thresholds for community navigation.

Method

Participants

We employed a cross-sectional design and recruited TBI participants from a specialized in-patient brain injury unit in a comprehensive rehabilitation hospital. Inclusion criteria were (a) age 18 years or older with a recent (within three months of injury) moderate to severe TBI according to the American Congress of Rehabilitation Medicine (ACRM, 1993) Guidelines confirmed by radiologic findings, (b) ambulating with independence or supervision with full weight-bearing on all extremities, and (c) within Rancho Levels Six through Eight, so as to encom-pass persons in later stage recovery affording an appropriate comprehension of test procedure and instructions. Participants were required to understand instructions in the English language. We confirmed Rancho classification through the medical record or examination by the senior physical therapist (Flannery, 1995). Exclusion criteria were (a) medical instability, (b) visual deficits such as legal blindness, (c) chronic neuromuscular conditions, (d) orthopedic weight-bearing restrictions, and (e) severe cardiopulmonary compromise. Control participants were healthy individuals matched according to age (three years), gender, stature, and ethnicity. All participants signed the informed consent. The study was approved by both the University Institutional Review Board and Hospital Medical Executive Committee.

Measures

We collected participants' anthropometric measures, including height and weight, and blood pressure. Both control and TBI groups performed subsequent gait and balance tests, and we randomized the test order to minimize test order bias. We administered three measures of gait performance to capture distinct dimensions of locomotion: functional mobility, velocity, and dual task ability. We utilized the Timed Up and Go Test (TUG) to measure functional mobility (Podsiadlo & Richardson, 1991). In this test, participants were instructed to stand from a uniform armchair, walk a three meter path to a designated floor tape marker, turn around, and proceed back to the chair. The TUG instrument dem-onstrated concurrent validity with the Berg Balance Scale (.81) and Barthel Index (.78) and predictive validity for falls (Podsiadlo & Richardson, 1991; Shumway-Cook, Brauer, & Woollacott, 2000). Psychometric stability was further supported by within-session reliability (.86) for persons with TBI (Katz-Leurer, Rotem, Keren, & Meyer, 2008).

Gait velocity was obtained using the 10 Meter Walk Test (Peters, Fritz, & Krotish, 2013). On this instrument, participants traversed 10 m at their normal, self-selected speed. Additional zones were marked beyond course borders to afford acceleration and deceleration intervals. The examiner used a stopwatch for timing the 10 m sector. Descriptive gait speed values have been reported by age, gender, and diagnosis (Bohannon, 1997; Steffen, Hacker, & Mollinger, 2002). Test–retest reliability for individuals with TBI has been reinforced by robust reliability intraclass correlations for self-selected (.96) and fast past (.96) speeds (Hirsch, Williams, Norton, & Hammond, 2014).

The Walking and Remembering Test (WART) incorporates a dual task memory superimposed upon a modified gait course (McCulloch, Mercer, Giuliani, & Marshall, 2009). Participants were instructed to walk at their self-selected speed along a narrow path while remembering a four-digit sequence. The truncated gait pathway was 19 cm wide and 6.1 m long. Velocity, the number of steps deviating from the path, and the digits reported back at the end of the test were recorded. This test battery assesses concomitant cognitive and motor tasks and reflects attentional division characteristic of daily life situ-ations (McCulloch, Buxton, Hackney, & Lowers, 2010). The WART demon-strated appropriate content validity, interrater reliability (>0.97), and test–retest reliability (.79) in both young and older adults (McCulloch et al., 2009). Extended use of the instrument has included persons with acute brain injury (McCulloch, 2006).

The Fullerton Advance Balance Scale (FABS) is a multidimensional test designed to identify higher level balance instability among community-dwelling older adults (Rose, Lucchese, & Wiersma, 2006). Tasks involved in the battery include a step up and over activity, tandem walk, two-footed jump, and back-ward lean task. Each of the 10 items is scored using a 0 to 4 point ordinal scale, with higher scores denoting better performance. Forty total points are possible. Metric support of the instrument has been confirmed by strong test–retest (.96) and interrater reliability (.94–.96) and convergent validity (.75) with the Berg Balance Scale (Klein, Fiedler, & Rose, 2011; Rose et al., 2006).

The MCTSIB quantifies sway velocity under four sensory conditions on a static forceplate. Individual sensory conditions are measured, along with total composite sway and center of gravity alignment (Navalon et al., 2014). Participants are required to maintain their balance in four conditions (10-s dur-ation each): eyes open and eyes closed standing on a firm surface, followed by eyes open and closed trials while standing on foam. Three trials are performed for each condition. A summed composite sway velocity score is calculated. Performance values closer to zero indicate stable control with minimal sway. The MCTSIB has been utilized previously with persons with TBI and exhibited responsiveness to change among individuals with head injury (Navalon et al., 2014). The test has also exhibited appropriate test–retest reliability in healthy adults (0.91–0.97) and select neurologic (0.91) conditions (Hageman, Leibowitz, & Blanke, 1995; Suttanon, Hill, Dodd, & Said, 2011).

Statistical Analyses

Statistical analyses included descriptive statistics (M and SDs) for demographic and physical performance variables. Independent t tests (continuous variables) and chi-square analyses (categorical variables) were performed for group demo-graphic differences. Bivariate analyses included one-way analysis of variance tests for gait and balance test comparisons between control and TBI cohorts, with group demographic differences treated as covariates (analysis of covari-ance). A multivariate analysis of covariance was calculated to assess differences between the aggregate sensory conditions and overall composite scores collect-ively on the MCTSIB. Post hoc comparisons further analyzed differences in each separate sensory condition.

An initial power analysis was performed based upon previous reports analyz-ing TBI cohort differences with counterpart controls to meet an effect size of .80 (Basford et al., 2003; Chou et al., 2004). Preliminary intraclass and Kappa coef-ficients were completed on all physical performance tests to establish intertester reliability (>.90) prior to subject enrollment and protocol testing. Significance was set at the .05 level. For individual sensory conditions on the MCTSIB, an adjusted significance level ($p < .01$) was utilized to account for multiple compari-sons. SPSS Version 24 was used for statistical analyses.

Results

We tested 20 individuals with TBI (M age = 42.6, standard deviation [SD] = 19.5 years) and 20 corresponding age-matched controls. Participants in the TBI group were predominantly male, Caucasian, and lived with a spouse or family (Table 1). Participants sustained moderate to severe injuries necessitating an in-patient rehabilitation stay; moreover, TBI severity extended beyond established thresholds for mild TBI or concussive injury according to the ACRM (1993) and World Health Organization, given participants' extended loss of consciousness, complications, prolonged posttraumatic amnesia, and sustained Rancho neuro-cognitive deficits (Ruff, Iverson, Barth, Bush, & Broshek, 2009). At the time of testing, 12 persons (60%) were classified at the Rancho Level VI Stage, 6 (35%) at Level VII, and 1 (5%) was at Level VIII. Mechanisms of injury included the following: (a) 35% motor vehicle accidents, (b) 45% falls, (c) 10% violence, and (d) 10% additional causes. The mean time since injury was 33.8 (SD = 15.0) days. The mean Glasgow Coma Scale rating at the time of injury was 5.3 (SD = 6.4). Fourteen (70%) participants sustained hematomas, with 10 (50%) having had skull fractures. Three participants (15%) experienced postinjury seizures. No significant age differences or demographic characteristics were noted between groups. Individuals with TBI demonstrated a significantly lower body mass index (BMI) compared with controls, $t(38) = 2.2$, $p = .03$.

Participants in the TBI group performed significantly slower on the TUG, gait velocity, and Walking and Remembering measures (Table 2). Compared with controls, the TBI group also demonstrated significantly more steps deviating from the gait course ($p = .006$; 95% confidence interval [CI]: [2.9, 5.1]) and fewer digits recalled ($p = .03$, 95% CI: [.14, 1.5]). Participants with TBI displayed significantly lower performance on the FABS ($p < .001$, 95% CI: [10.3, 19.2]) and higher sway velocity on all MCTSIB conditions, (5, = 7.48, $p < .001$, including the composite score. Statistical significance was not attenuated when adjusting for the BMI covariate.

Discussion

Recovery from TBI presents a variable trajectory with respect to time and out-comes. Although most persons progress to independent ambulation following rehabilitation, restrictions are apparent (Katz, White, Alexander, & Klein, 2004; Labi, White, Alexander, & Klein, 2003). Our findings elucidate the magnitude of gait and balance insufficiency in the acute phase of recovery nearing the end of moderate to severe TBI patients' acute rehabilitation juncture. Participants included a representation of persons typically at risk of TBI, including both young adults and persons over the age of 65 years with injuries sustained from vehicular accidents, acts of violence, and falls (Center for Disease Control and Prevention, 2016; Salottolo et al., 2017). Although our participants were designated at the later stages of the Rancho continuum with cognition labeled at the Rancho-Appropriate level at the time of this testing, significant physical performance deficits were evident and included slower gait and poorer balance modulation compared with controls. Although often designated as "higher level" in cognitive recovery, these individuals displayed significant motor behavior constraints in speed and sway.

The TUG instrument is widely used with multiple diagnostic groups to quan-tify functional mobility and reflects simple household stand and walk tasks. The test has been less frequently studied in individuals with TBI than with stroke, Parkinson disease, or community-dwelling older adults (Bonnyaud et al., 2016; Campbell, Rowse, Ciol, & Shumway-Cook, 2003; Shumway-Cook et al., 2000). Compared with healthy controls, times were significantly slower. Scores on these tests from our TBI participants were also slower than reported normative values (Steffen et al., 2002). Our TBI participants' mean TUG score of 13.5 s mirrored one reported cut-off score for fall risk and exceeded another (Kojima et al., 2015; Shumway-Cook et al., 2000). This marker has become a point of debate, however, with three systematic reviews citing caution with TUG threshold scores that dichotomize predictive faller versus nonfaller status (Barry, Galvin, Keogh, Horgan, & Fahey, 2014; Beauchet et al., 2011; Schoene et al., 2013).

Considered a vital sign, walking speed has been linked to falls and global health decline (Fritz & Lusardi, 2009; Viccaro, Perera, & Studenski, 2011). Our participants with TBI demonstrated a mean velocity of .96 m/s, significantly slower than their age-matched controls and than scores in published norms (Bohannon, 1997; Steffen et al., 2002). Our findings corroborate previous reports that persons with TBI ambulate with a slower speed following their injury. These velocities have ranged from 1.07 m/s to 1.41 m/s (Valleé et al., 2006; G. Williams et al., 2009). Our mean TBI group self-selected velocity was somewhat slower than previous studies reported; however, our participants were considerably more acute in their postinjury recovery. Proposed reasons for speed reduction are mixed; furthermore, G. P. Williams and Morris (2011) and G. P. Williams, Schache, and Morris (2013a) reported that ankle joint power was a significant determinant of high-level mobility, though tests of static balance such as single-leg stance did not substantially predict speed.

Limited gait velocity imposes challenges for community navigation and activ-ity. Requisite speeds greater than 1.0 m/s are required to meet crosswalk demands at signals or traffic lights in some geographic locations (Selbach et al., 2014). Speeds slower than 1.0 m/s necessitate interventions for fall risk (60). Individuals often express their goal to run and return to their previous level of activity; prognostically, a speed of 1.0 m/s is a strong predictive marker that an individual will run after their injury (G. P. Williams, Schache, & Morris, 2013b).

Dual task deficits have been reported following TBI (McFadyen et al., 2003). Our participants with TBI demonstrated both a slowed gait pattern and number of steps off path when challenged with simultaneous semi-tandem walking and word retrieval. Chou et al. (2004) found analogous findings when participants were required to negotiate obstacles of varying heights. Our data also support previous work where participants demonstrated a slower gait velocity when similarly confronted with a narrowed ambulation path (McFadyen et al., 2003). Although our control participants were able to recall the digit span in all cases, most participants with TBI could recall at least three digits. Participants may have prioritized the allocated memory task at the expense of gait navigation when confronted with the task interference challenge.

The FABS is a test which examines advanced balance control through com-pletion of 10 component tasks, including curb negotiation and reactive stepping. The tool has been used to examine balance in a variety conditions, including persons with Parkinson disease, fibromyalgia, and breast cancer (Cherry et al., 2012; Schlenstedt et al., 2012; Wampler et al., 2007). The instrument was selected to discriminate individuals' varying balance abilities and avoid ceiling effects encountered with other assessments (Pardasaney et al., 2012). The test also con-tains specific items particularly relevant to individuals with TBI. For example, the tandem task has typically yielded challenges for this population, even in the more chronic stages of recovery (Walker & Pickett, 2007). The unique backward lean category is also pertinent, given the association between injury severity in older adults and backward falls. Our participants' mean score of 24 points fell below the reported cut-off for fall risk (Hernandez & Rose, 2008). Interestingly, not all age-matched controls received a perfect score.

Balance degradation following TBI reflects an inability to maintain altered base of support positions, modulate center of mass, and modulate postural sway (Buster, Chernyavsky, Harms, Kaste, & Burnfield, 2016). Our participants' MCTSIB posturographic composite balance scores fell below their age-matched controls, indicating a greater level of sway when individual sensory conditions were either augmented or subtracted. Previous studies have cited similar sway aberration in forceplate trials among individuals with TBI compared with nor-mative or control group values (Navalon et al., 2014; Pickett et al., 2007). Pickett et al. (2007) noted a significantly greater sway on the composite six-condition Sensory Organization Test compared with normative values among 21 individ-uals recovering from TBI. Sensory reweighting insufficiency occurred whether on a compliant forceplate or on foam as in the present study. Consistent pos-turographic reports illustrate vestibular correction inadequacy when confronted with discordant sensory information or blinded vision (Kaufman et al., 2006; Pickett et al., 2007).

An unexpected demographic finding included the BMI disparity between cohorts. Our participants with TBI demonstrated a lower BMI compared with counterpart controls. Although the prevalence of obesity among survivors of TBI has previously been reported as high as 19%, only two of our participants (10%) fell into the Class One Obesity category (Brown et al., 2006). Our findings coincide with data reported by Majdan, Brazinova, Wilbacher, Rusnak, and Mauritz (2015), where the authors noted a median BMI of 25.6 kg/m^2 in their sample of 683 participants and approximately 10% were obese.

Our findings contribute to research describing balance and locomotor recov-ery from TBI at a key point in rehabilitation. This study's outcomes can assist others in determining discharge needs and resources. A critical theme in head trauma rehabilitation is fall risk, particularly since individuals with TBI may have sustained their injury from a fall; furthermore, impaired postural stability following injury can predispose them to future falls.

Impaired gait and balance can be associated with latter Rancho stage cognition deficits, including impaired judgment and abstract reasoning, and result in fall incidents during an in-patient hospitalization stay (McKechnie, Pryor, & Fisher, 2015). Although our partici-pants generally scored lower (or poorer) on several standardized outcomes, the degree of fall risk is difficult to calibrate, given the paucity of studies with recognized sensitivity and specificity cut-off scores for fall risk in this population. Persons with a fall history typically have demonstrated significantly poorer scores on select balance measures (McCulloch et al., 2010). Individuals with more severe injuries and multisystem involvement exhibit greater fall risk (McKechnie, Fisher, & Prior, 2016).

Among the strengths of this study, to our knowledge, this is the first study to compare balance and gait performance in adults with a relatively acute TBI, using a blend of clinical measures and instrumented technology. The assessment tools we used, including forceplate testing, can be administered in a variety of clinical settings to comprehensively examine these attributes of physical performance. The use of the FABS instrument affords challenging task assessment relevant to patients' return to activity participation. Performance findings serve as a conduit to assess impending discharge needs and follow-up. Likewise, deficits in gait and balance necessitate additional interventions for community reintegration and potentially justify a longer hospital length of stay to reimbursement organizations.

Limitations of this study include its cross-sectional design with temporal inference restraints. In addition, lower extremity spasticity was not formally assessed, perhaps contributing to the differences in gait speed we revealed (G. Williams, Banky, McKenzie, & Olver, 2017). An additional limitation included the limited participant sample size and ethnic diversity, though the sample tended to parallel the diversity inequity commonly seen among rehabili-tation facilities for persons receiving therapy following TBI (Meagher, Beadles, Doorey, & Charles, 2015).

Conclusions

Our exploratory study provides a profile of the clinical picture of individuals with TBI in the acute phase of their injury. Findings also add to existing studies which describe gait and balance performance during the recovery trajectory. Gait and TUG velocities are slower compared with control participants, along with dual task ambulation. Diminished balance performance, including dimin-ished adaptive sensory reweighting, is also evident. Speed and sway deviations in physical performance heighten the potential for falls; moreover, gait deficits can restrict participation in both community and home-based activities. Performance scores ultimately support the need for continued rehabilitation to facilitate improved locomotion and reduce fall risk. Interventions have ranged from body weight supported treadmill training to specialized therapies such as Tai Chi and vestibular rehabilitation (Bland, Zampieri, & Damiano, 2011).

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Table 1.

Demographic Data: Participants With TBI.

Subject Demographic Profile	Participants with TBI (n = 20) M (SD) [95% CI]
Age	42.6 (19.5) [95% CI: 33.4, .51.7]
Gender	
Male (%)	14 (70)
Ethnicity	
Caucasian (%)	15 (75)
African American (%)	2 (10)
Hispanic (%)	3 (15)
Injury characteristics	
Initial Glasgow Coma Score (M, SD)	5.3 (6.4) [3.2, 7.4]
Days since injury (M, SD)	33.8 (15.0) [10.5, 23.3]
Mechanism of injury	
Fall (%)	9 (45)
Motor vehicle accident (%)	7 (35)
Act of violence (%)	2 (10)
Other trauma (%)	2 (10)
Rancho level of cognitive function	
Level 6 (%)	12 (60)
Level 7 (%)	7 (35)
Level 8 (%)	1 (5)
Complications	
Skull fractures (%)	10 (50)
Occipital (%)	5 (25)
Frontal (%)	2 (10)
Temporal (%)	1 (5)
Combination (%)	2 (5)
Hematomas (%)	14 (70)
Subdural (%)	5 (25)
Intraventricular (%)	3 (15)
Subarachnoid (%)	2 (10)
Combination (%)	4 (20)
Seizures (%)	3 (15)

Note. TBI = traumatic brain injury; CI = confidence interval; SD = standard deviation.

Table 2.

Comparison of Persons With TBI and Controls.

Participant profile	Persons with TBI (n = 20) M (SD) [95% confidence interval]	Controls (n = 20) M (SD) [95% confidence interval]	p	Mean difference [95% confidence interval]
Age (years)	42.6 (19.5)	43.3 (19.2)	.90	11.6, 13.1
	[33.4, .51.7]	[34.3, 52.3]		
Body mass index (kg/m^2)	24.3 (4.4)	27.6 (4.9)	.03*	0.28, 6.3
	[22.2, 26.4]	[25.3, 29.8]		
Systolic blood pressure (mm Hg)	120.6 (15.2)	127.5 (12.1)	.13	2.0, 15.8
	[113.3, 128.0]	[121.9, 133.1]		
Diastolic blood pressure (mm Hg)	77.1 (7.3)	80.7 (8.3)	.15	1.4, 8.7
	[73.5, 80.6]	[76.8, 84.6]		
Comorbid conditions	(#, %)	(#, %)		
Heart disease	6 (30)	2 (10)	.06	
Diabetes	2 (10)	1 (5)	.30	
Arthritis	2 (10)	3 (15)	.50	
Depression	7 (35)	4 (20)	.24	
Gait performance	M (SD)	M (SD)		
Timed up and go test (s)	13.5 (4.9)	7.7 (1.4)	<.001*	8.3, 3.4
	[11.2, 15.8]	[7.1, 8.4]		
10 m walk test (m/s)	.96 (2.6)	1.5 (2.2)	<.001*	0.37, 0.70
	[.84, 1.1]	[1.4, 1.6]		
Walking and remembering test				
Gait time (s)	9.9 (2.1)	5.8 (2.1)	<.001*	5.8, 2.9
	[8.9, 10.9]	[4.8, 6.8]		
Number of steps off path (#)	1.9 (2.5)	0.1 (0.3)	.006*	2.9, 0.51
	[0.79, 3.0]	[0.04, 0.24]		
Digits recalled (#)	3.4 (1.5)	4.0 (0.0)	.03*	0.14, 1.5
	[2.7, 4.0]			

Participant profile	Persons with TBI (n = 20) M (SD) [95% confidence interval]	Controls (n = 20) M (SD) [95% confidence interval]	p	Mean difference [95% confidence interval]
Balance control				
Fullerton Advanced Balance	24 (8.8)	38.8 (2.4)	<.001 *	10.3, 19.2
Scale (#, max 40)	[19.9, 24.0]	[37.7, 39.9]		
Modified clinical test for sensory interaction in balance (deg/s)				
Eyes open (Firm)	0.41 (2.2)	0.23 (0.10)	.004 **	.29, .06
	[0.30, 0.51]	[0.23, 0.26]		
Eyes closed (Firm)	0.61 (0.20)	0.37 (0.40)	<.001 **	.53, 0.17
	[0.44, 0.78]	[0.23, 0.30]		
Eyes open (Foam)	1.9 (1.7)	0.70 (0.20)	.005 **	2.1, 0.4
	[1.0, 2.7]	[0.55, 0.77]		
Eyes closed (Foam)	4.4 (1.5)	1.7 (1.0)	<.001 **	3.3, 1.6
	[3.6, 5.1]	[1.2, 2.2]		
Composite	1.8 (0.77)	0.75 (0.29)	<.001 **	1.4, 0.62
	[1.5, 2.2]	[0.61, 0.89]		

Note. TBI = traumatic brain injury; SD = standard deviation.

* p <.05;

** p <.01.