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Reliability of the sub-components of the instrumented timed up and go test in ambulatory children with traumatic brain injury and typically developed controls

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ABSTRACT

Background: Studies have evaluated the test-re-test reliability of subcomponents of the timed up and-go test in adults by using body-worn inertial sensors. However, studies in children have not been reported in the literature.
Research Question: To evaluate the within-session reliability of subcomponents of a newly developed electronically augmented timed 'upand-go' test (EATUG) in ambulatory children with traumatic brain injury (TBI) and children with typical development (TD).
Method: The timed up and go test was administered to twelve consecutive ambulatory children with moderate to severe TBI (6 males and 6 females, age 10.5 ± 1.5 years, range 8–13 years, during inpatient rehabilitation at 27.0 ± 11.8 days following injury) and 10 TD age and sex-matched children (5 males and 5 females, 10.4 ± 1.3 years, range 8–11 years). Participants wore a single chest-mounted inertial measurement sensor package with custom software that measured angular and acceleration velocity and torso flexion and extension angles, while they performed 6 trials of the EATUG test. Measures were derived from the overall time to complete the TUG test, angular velocity and angular displacement data for torso flexion and extension during sit-to-stand and stand-to-sit segments and both mean and peak angular velocities for two turning segments (i.e. turning around a cone and turning-before-sitting).
Results: Within-session reliability of the subcomponents of the TUG test for children with TBI assessed by the intra-class correlation coefficient was ICC (1,1) = 0.84, (range 0.82–0.96), and for TD children ICC (1,1) = 0.73, (range 0.53–0.89). Scores on Total Time, maximum torso flexion/extension angle and peak flexion angular velocity during sit-tostand, and peak turn angular velocity for both turns around the cone and turns before sitting were lower for children with TBI than for TD children ($p \leq 0.05$).
Significance: The EATUG test is a reliable measure of physical function in children with TBI who are being discharged from inpatient rehabilitation.

1. Introduction

A primary goal of pediatric inpatient rehabilitation is to help patients regain their gait related functional mobility, and often regaining mobility is the primary aim of the patient. While most children with traumatic brain injury (TBI) recover the ability to walk independently, gait related mobility deficits remain common in ambulatory children after TBI [1–3]. Previous research has identified that functional impairments such as strength, agility and coordination in children who have suffered TBI can last several years beyond the initial injury [4]. Rehabilitation interventions which target these balance and mobility deficits are often needed for children to regain optimal functional independence [5]. This research underscores the need for reliable and comprehensive tests of physical function that will aid clinicians in diagnosing mobility deficits experienced in children post-TBI.

An often-used performance-based test of functional mobility in pediatric rehabilitation is the timed 'up-and-go' (TUG) test [6–12]. A single metric, the total time, in seconds, to completion is recorded.

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Within-session intra-class correlation coefficient (ICC) values for the TUG test in children with TD range from 0.80 to 0.89 [8,12], from 0.98 to 0.99 for children with cerebral palsy [9,14], 0.82 to 0.93 for children with Down syndrome [9,10], and 0.92 for children with acquired brain injury [8]. In children with severe chronic TBI, 8.7 ± 3.5 years of age and 7.5 ± 3 months post-injury at the time of testing, Katz-Leurer reported the within-session ICC for total time as 0.86 [8].

It has been stated that the use of a single TUG test metric lacks information regarding the subcomponents of the TUG test [10,14] (e.g., standing up from a seated position, turning around a cone, turning-before-sitting, sitting down). Instrumenting the TUG test may provide relevant additional clinical information about the subject's mobility [13,14]. The TUG was chosen as our physical function test as scholars argue the TUG test is a comprehensive test of mobility as it requires standing, turning, and sitting tasks in addition to forward moving gait [15].

In two studies in which ambulatory adults with mild to severe Parkinson's disease performed the TUG test wearing an inertial sensor attached to the lower trunk near the spine, subcomponents discriminated between mild and severe disease severity, and revealed ICC test-re-test reliability coefficients of 0.38–0.47 for the sit-to-stand segment, 0.73–0.89 for the turning around a cone segment, 0.73–0.88 for turn-to-sit segment, and 0.18–0.63 for the standing-to-sitting segment [15,16]. In a stroke population, the instrumented TUG test was found to have fair to excellent test-retest reliability in differentiating patients from healthy controls (ICC 0.43–0.99) [14]. Despite these advances in instrumented TUG tests in adults, studies on the subcomponents of the instrumented TUG test in children have not been reported in the literature.

The main purpose of the present study was to establish the within-session test-re-test reliability of an instrumented TUG test among ambulatory children with a diagnosis of moderate to severe TBI who are being discharged from inpatient rehabilitation, compared to age and sex-matched controls. We hypothesized that the test-re-test reliability would be high for children with TBI and children with TD. The second purpose of this study was to quantitatively compare the subcomponent results of children with TBI and children with TD. We hypothesized that children with TBI would have lower scores on TUG subcomponents compared with children with TD.

2. Method

2.1. Participants

The study was approved by the (Carolinas Medical Center) Institutional Review Board. All parents completed an institutionally approved informed consent form and assent was sought from children 8 years of age and older before participation in the study.

A convenience sample of 12 children (6 boys and 6 girls, 10.5 ± 1.5 years) with TBI were recruited from the (Levine) Children's Hospital, in Charlotte, North Carolina. Consecutive pediatric admissions to inpatient rehabilitation for TBI were screened (n = 95). Subjects were selected according to the following criteria: (1) first TBI, (2) currently 7–15 years of age, (3) admitted to the (excluded for peer review) Children's Hospital Rehabilitation service at (excluded for peer review) Medical Center having sustained a moderate to severe TBI (Glasgow Coma Scale (GCS) score at admission of 3–12), (4) able to give informed assent and parent/guardian able to consent, (5) able to ambulate 10 m without physical assistance from another person, without an assistive device (foot orthoses permitted), (6) no longer in post-traumatic amnesia (PTA) as indicated by a score of ≥109 on 2 serial administrations (within 24 h) of the standardized Children's Orientation and Amnesia Test [18–20], (7) English speaking. Participants with TBI were excluded if they demonstrated a speech language expression deficit (e.g., aphasia) or had a medical record diagnosis of attention deficit disorder.

Table 1
Subject characteristics for the children with traumatic brain injury and children with typical development. *values are mean ± SD or number; TBI, traumatic brain injury; TD, typical development; GCS, lowest Glasgow Coma Scale score before admission to inpatient rehabilitation; COAT, the Children's Orientation and Amnesia Test; WeeFIM®, Functional Independence Measure for Children; BMI, body mass index (kg/m^2); P, probability value; n, number of participants; cm, centimeter; kg, kilogram; m, meter; PTA, post traumatic amnesia; Orthotic use, n = 1 ankle foot orthosis, n = 1 cervical thoracic. Data on lesion location were available for all participants with TBI and included: Laterality: bilateral = 6, right = 4, left = 2; Type: intraparenchymal hemorrhage = 3, multi-compartment = 3, subdural hematoma = 2, subarachnoid hemorrhage = 2, diffuse axonal injury = 1, temporal bone fracture = 1. Ninety-five consecutive pediatric TBI patients were screened, 12 were enrolled. 83 were excluded because they did not fulfill the study criteria due to: Age: n = 36, Unable to ambulate: n = 11, Not admitted to inpatient pediatric rehab hospital: n = 10, Assistive device: n = 6, Mild TBI: n = 4, Discharge from inpatient rehabilitation hospital before research assistant able to approach: n = 4, Other (dual diagnosis TBI/Spinal Cord Injury, Blind, hypoxic ischemic encephalopathy, infectious disease, Attention Deficit/Hyperactivity Disorder diagnosis): n = 11, Patient declined to participate: n = 1. While some of the patients in our study needed moderate assistance to complete 150 feet of ambulation (WeeFIM) [31], they could all complete the 6 feet of ambulation required by the TUG protocol without assistance.

	TBI (n = 12)	TD (n = 10)	P
Age (years)	10.5 ± 1.5	10.4 ± 1.3	0.87
Males	6	5	
Race (white)	9	9	
Height (cm)	148.0 ± 15.4	147.9 ± 13.8	0.98
Weight (kg)	40.9 ± 10.3	41.1 ± 8.7	0.95
BMI (kg/m^2)	18.7 ± 4.5	18.9 ± 4.2	0.88
Education (years)	5.1 ± 1.4	5.2 ± 1.1	0.83
Leg length - right (cm)	75.1 ± 6.8	76.1 ± 4.8	0.71
Leg length - left (cm)	75.0 ± 6.7	76.1 ± 4.8	0.68
Orthotic use (yes)	2	0	
GCS	5.3 ± 2.9	–	
COAT	118.5 ± 3.0	–	
Wee-FIM®	5.8 ± 1.2	–	
Days from injury to clearing PTA	27.08 ± 11.89	–	

Ten age and sex-matched TD children (5 boys and 5 girls, 10.4 ± 1.3 years) served as controls. Selection criteria for the controls were ambulatory without a history of musculoskeletal or neurological injuries, and enrolled in an age-appropriate school grade in North Carolina at the time of testing; though they were not screened, they were thought by the school system to have TD. Previous studies have shown that comparisons using data of matched pediatric control subjects are more valid than comparisons using test norms because biases resulting from premorbid characteristics, maturational effects, and different test settings are minimized [1,8,21–23]. Descriptive characteristics of the TBI and the TD children are presented in Table 1. There were no significant differences between groups in age, body weight, height, BMI, leg length, and years in school.

2.2. Procedures

2.2.1. Clinical measures

Clinical data were collected in terms of leg length (derived by measuring the distance from the anterior superior iliac spine to the lateral malleolus of each leg, with subjects lying supine on a padded plinth, using a tape measure) [24], standing height (in cm), body weight (in kg), body mass index, and race. In the children with TBI, age at trauma, etiology, assistive devices, number of days since TBI on day of testing, lesion location and current medications were derived from the electronic medical record. The Children's Orientation and Amnesia Test score (COAT) [19], and the locomotion-variable score on the Functional Independence Measure for Children (WeeFIM®) were administered to all children with TBI. The COAT [19,20] is an objective,