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Original Research

Validity and Responsiveness of the Portable Warrior Test of Tactical Agility After Rehabilitation in Service Members With Mild Traumatic Brain Injury

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Abstract

Objective. The Portable Warrior Test of Tactical Agility (POWAR-TOTAL) is a performance-based test designed to assess active-duty service members diagnosed with mild traumatic brain injuries (mTBIs) and could potentially inform return to duty decisions. To examine the validity and responsiveness of the POWAR-TOTAL measure, this study collected self-reported and performance measures by active-duty service members before and after an episode of physical therapist care.
Methods. Seventy-four individuals, enrolled in care for mTBI symptoms at 1 of 2 concussion specialty Intrepid Spirit Centers, were examined the week that they initiated physical therapy with the intention to return to active duty. Self-reported measures of concussion symptoms, pain, posttraumatic stress, headache, dizziness, and sleep quality were used, as were concurrent measures of mobility and balance. The POWAR-TOTAL task (motor and cognitive skills in single and dual-task conditions) was administered. Forty-nine active-duty service members returned for posttherapy testing using the same test battery. Effect sizes for change in measures were calculated. Construct validity was assessed by correlating change scores on POWAR with concurrent self-report and mobility measures. Responsiveness was evaluated using an anchor-based approach.
Results. Significant improvements in self-reported and performance-based measures, including POWAR, were observed after therapy with moderate to large effect sizes. Improvement in POWAR performance correlated with improvement in both performance and self-reported measures. After therapy, individuals who registered improvement on the Patient Global Impression of Change scale demonstrated significantly faster POWAR motor performance than those who rated little or no improvement in their condition.
Conclusion. The POWAR-TOTAL captured improvement on a military-specific task after completing physical therapy for mTBI and could serve as an indicator of physical recovery and readiness for return to duty.
Impact. Challenging cognitive and motor measures for service members may aid in the assessment of recovery and the ability to successfully return to duty after concussion as part of a comprehensive examination approach.

Keywords: Concussion, Functional Assessment, Military, mTBI, Multi-Task Assessment, Return to Duty

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Introduction

Over 470,000 Active Duty Service Members (ADSM) have sustained a traumatic brain injury (TBI) since 2000. Most of these injuries are classified as concussion or mild TBI (mTBI).[1] ADSMs are often able to return to unrestricted duty in 2 to 4 weeks, following rest and a progressive return to activity process,[2] but some demonstrate longer standing symptoms and impairments that required rehabilitation.[3] Persistent impairments could impede performance of specialized military skills required for active duty, leading to an increased risk of injury or risk to others in more dangerous forward operations. Therefore, it is important to ensure that an ADSM diagnosed with mTBI has recovered and is ready to return to full duty including deployment to dangerous environments.

Symptom self-report as an indicator of recovery has limitations, as ratings are subject to under- or overreporting effects, and may be influenced by social pressures associated with military service[4,5] or for other reasons associated with personal or professional gain. Many self-report measures used for concussion, including the Neurobehavioral Symptom Inventory (NSI), a standard measure in military practice,[6] lack specificity. Common symptoms may be associated with other conditions or stressors.[7] Observational or performance measures offer benefits of detecting impairments to corroborate symptom report and may also serve as markers of physical performance necessary for military duty.

Most balance and mobility measures commonly used by physical therapists do not incorporate high level challenging tasks typical of military training. Simple tasks such as standing or walking may not reveal subtle impairments that ADSMs experience beyond the acute period postinjury. Individuals who seek rehabilitation care in the military may be weeks or even months postinjury, resulting in ceiling effects with more basic measures, erroneously implying recovery, resulting in premature return to training, increased risk of injury to the ADSM, and possibly negatively affecting duty and mission capability. Tasks that reflect the dynamic and challenging conditions faced by ADSMs may be more sensitive to subtle symptoms associated with mTBI including dual-task (DT) or multitask conditions.[8,9] Clinically feasible ecologically valid measures that assess exertional or DT abilities would fill a gap in concussion care in the military.

The Portable Warrior Test of Tactical Agility (POWAR-TOTAL or POWAR) is a brief exertional DT assessment that could be administered in a typical clinic or a more austere setting using readily available equipment (Figure). Construct validity of POWAR has been previously described, and it discriminates between ADSM with concussion and their fit for duty ADSM peers via simple observational measures[10] and inertial sensor measures.[11] Faster performance of the POWAR motor measure was significantly associated with self-reported physical readiness for deployment.

This paper addresses the responsiveness of POWAR in a group of ADSM diagnosed with concussion after completing physical therapy. Self-reported measures and validated performance measures of balance and mobility were measured before and after an episode of physical therapy to examine the relationship of change on POWAR with change on those measures to address construct validity. A rating of overall improvement, the Patient Global Impression of Change (PGIC),[12] provided an anchor for evaluating responsiveness of the POWAR. Guidance for interpretability was also calculated for motor performance on the POWAR task.

Methods

This pre–post longitudinal study was conducted at Intrepid Spirit Center (ISC) Clinics at Womack Army Medical Center at Fort Liberty (named Fort Bragg at the time of this study) in Fayetteville, NC and Madigan Army Medical Center at Joint Base Lewis-McChord in Tacoma, WA. ISCs are specialized intensive outpatient programs that serve the needs of individuals in the military who have health needs following mTBI. As a population, these individuals often have a history of multiple mTBIs and typically seek care for persistent complaints that may be driven by more than a single symptom or impairment. The study received approval from the Regional Health Command-Atlantic and Madigan Army Medical Center Institutional Review Boards and all participants provided informed consent.

Participants

Participants were ADSM (18–45 years) stationed at either Fort Liberty or Joint Base Lewis-McChord who were recruited from ISCs and were initiating treatment related to complaints associated with mTBI that was documented in the medical record and sustained greater than 2 weeks, but less than 2 years prior to enrollment. Exclusion criteria included confirmed pregnancy, presence of a major psychiatric diagnosis or medical condition that would prevent performance of cardiovascular exercises or rendered them unable to perform moderate exertion for up to 30 minutes, lifetime history of severe or penetrating head injury, activity restriction that limited ability to run or perform military exercise for up to 10 minutes, and deficits in vision or hearing that would prevent them from hearing test instructions or seeing test materials.

Measures and Procedures

Patients were scheduled for an initial test within a week of their initial physical therapist evaluation. The final test session was scheduled as close as possible to the patient's final physical therapist session or discharge from care by the physical therapist. The nature of and duration of physical therapist intervention was not controlled.

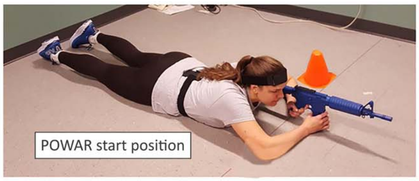
Participants completed a questionnaire and self-report surveys at both sessions that included demographic and military service information (Tab. 1). Self-report measures targeted impairment areas that could influence ability to resume active duty after mTBI: the NSI,[13,14] the Defense and Veterans Pain Rating Scale (DVPRS),[15,16] the Post Traumatic Stress Disorder Checklist-Civilian (PCL-C),[17,18] the Dizziness Handicap Inventory (DHI),[19] the Headache Impact Test (HIT-6),[20–22] and the Pittsburgh Sleep Quality Index (PSQI).[23] Measures were selected based on known reliability and validity, and were consistent with TBI Center of Excellence recommendations for military research.

There are no validated measures of tactical agility that could be used as a gold standard for validation. Since the POWAR task requires balance and the ability to run, we included measures of mobility and balance that were conducted at pre- and post-therapist test sessions to examine rates of change on the POWAR task in relation to change on those measures. The NeuroCom Sensory Organization Test

Visual acuity testing: Binocular visual acuity was assessed in standing using a Snellen Eye Chart. Vision line was recorded to assess acuity, with Line 8 reflecting 20/20 vision. Self-reported visual clarity for that line was recorded using an 11-point Likert Scale (0 = perfectly clear and stable; 10 = extremely blurry and/or unstable).

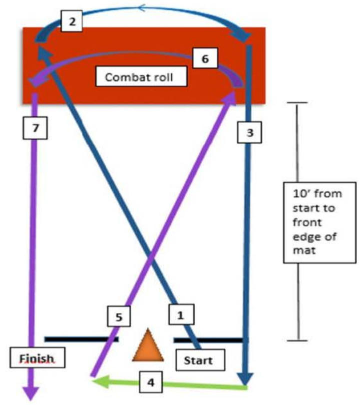
Cognitive task: A single task working memory task required the participant to remember an 8-item grid coordinate (eg, Echo-Bravo-4-2-9-6-3-7), a familiar type of military location description. If 4 or fewer of the 8 items of the grid coordinate were recalled, a second trial was conducted. The better of the two scores was recorded as the baseline single task cognitive score.

Motor task: The POWAR-TOTAL motor task is a rapidly performed mobility-agility maneuver that begins with the participant lying in the prone position while holding a simulated M16 weapon (Bluegun).



The participant quickly transitions to standing, runs diagonally 10 feet forward to a gym mat, completes a left-to-right combat roll, transitions to standing, runs straight backward to the start position, shuffles laterally around a cone, runs forward diagonally 10 feet to the opposite side of the mat, transitions to prone and completes a right-to-left combat roll, transitions to standing and runs backward again toward the end position (schematic in right panel).

The motor task was hand-timed and recorded. Movements were recorded via the AndroSensor application (v1.9.6.3, www.fivasim.com) on Samsung Galaxy cell phones using its triaxial accelerometers and gyroscopes. Phones were attached to the head and torso via adjustable neoprene straps. After a practice trial to assess safety and recall of the components of the task, up to two single task motor trials were performed.



Dual-task trials: Three dual-task trials combined the motor and cognitive tasks, each consisting of a new grid coordinate provided to the participant while in the start position. After a 1-second pause, the participant was signaled to begin the motor task with a ready, set, go command. Upon completion of each trial, the recalled grid coordinate items were recorded.

Rest and stopping criteria: Rest was allowed in between trials if needed. If a subject experienced symptoms that did not quickly resolve or there were safety concerns based on their performance, testing was halted prior to completing all trials.

Posttesting visual acuity: After the first single task trial and the final dual-task trial, visual acuity and clarity were reassessed using the same approach as at the beginning of the test.

Figure. Portable Warrior Test of Tactical Agility (POWAR-TOTAL) Testing Protocol.

Table 1. Demographic Variables

Variables	Total Sample Mean (SD) *n* = 74	Returned for Posttesting Mean (SD) *n* = 49	Lost to Follow-Up Mean (SD) *n* = 25
Age, y	29.6 (6.8)	29.2 (6.4)	30.4 (7.7)
Time in service, y	8.6 (6.2)	8.1 (5.9)	9.6 (6.8)
Number of deployments	3.6 (2.7)	3.9 (2.9)	3.2 (2.5)
	Range = 1–12	Range = 1–12	Range = 1–11
Time since recent concussion (mo)	7.8 (6.6)	7.6 (6.5)	8.1 (6.8)
Prior number of concussions	5.5 (6.4)	6.0 (7.5)	4.4 (3.1)
	Range = 1–40	Range = 1–40	Range = 1–10
Connor Davidson Resilience Scale[a]	74.5 (15.7)	73.8 (15.9)	75.7 (15.7)
Patient Global Index of Change[b]	N/A	4.7 (1.46)	N/A
Categorical variables	***n* (%)**	***n* (%)**	***n* (%)**
Sex			
Male	68 (91.9)	46 (93.9)	22 (88.0)
Female	6 (8.1)	3 (6.1)	3 (12.0)
Ethnicity			
Caucasian	55 (74.3)	39 (79.6)	16 (64.0)
African American	4 (5.4)	2 (4.1)	2 (8.0)
Hispanic / Latino	8 (10.8)	5 (10.2)	3 (12.0)
Other	7 (9.5)	3 (6.1)	4 (16.0)
Education			
High school	21 (28.4)	14 (28.6)	7 (28.0)
Some college/associates degree	44 (59.5)	28 (57.1)	16 (64.0)
Bachelor's degree or higher	9 (12.2)	7 (14.3)	2 (8.0)
Concussion history prior to this injury	58 (78.4)	40 (81.6)	18 (72.0)
No duty restrictions	33 (44.6)	21 (42.9)	12 (48.0)
Physically ready to deploy in 72 h	22 (29.7)	13 (26.5)	9 (36.0)

[a]Assessed at initial test session only. [b]Assessed at final test session only.

(SOT)[24] composite score, a test used by physical therapists to assess balance under varying sensory conditions, provided a measure of postural stability and balance. SOT was extracted from the medical record, or was completed by project staff at enrollment in the study if not administered by the treating physical therapist.

Participants also completed the revised High Level Mobility Assessment Tool (HiMAT),[25] which has been validated in a civilian population diagnosed with mTBI, and requires running and other higher level mobility tasks. Since testing was conducted in ISCs that are single story structures, the HiMAT without stairs was used, and the test was repeated concurrently with the POWAR test before and following therapy. POWAR may provoke symptoms from individuals with vestibular impairment given the transitional movements required in the motor task that may manifest in visuo-vestibular complaints. Therefore, we also extracted dynamic visual acuity test results [line(s) lost during horizontal head turning] from the medical record at the start of therapy, to measure the ability to stabilize visual images during head movement. In addition we tested vision for acuity and self-reported clarity at the beginning and following the POWAR test. If participants experienced an increase in symptoms or difficulty with task performance during testing, they were offered an opportunity to rest, drink some water, and after several minutes asked if they wish to resume or discontinue participation in the test. Participants were free to stop participation at any time, consistent with the informed consent process.

Participants who returned for the second test session completed a questionnaire which updated military service information collected at the pretreatment session and completed the same self-report, POWAR, and HiMAT measures. The PGIC was completed by the subject to characterize perceived change as a result of therapy intervention.

POWAR test procedures have been reported previously[10,11] with details summarized in the Figure. A prior version of this test that included a similar motor task demonstrated good interrater reliability,[26] and the cognitive task used in the task had strong interrater reliability in a prior study.[9] Visual acuity testing was conducted prior to and following the mobility components of the POWAR, using a Snellen chart and a visual analog scale rating of visual clarity that was used in a prior study.[8,9] Single-task (ST) motor and cognitive testing was followed by 3 trials of DT performance. An important factor to consider with the use of novel mobility and balance measures is the potential for practice or learning effects that confound interpretation of change in performance. As part of the larger POWAR study, which included 60 healthy fit for duty control ADSMs,[10,11] we tested a small sample ($n = 11$) of control subjects twice, approximately 1 month apart, to examine possible learning or practice effects.

Statistical Analysis

Data were entered and verified using Research Electronic Data Capture 209, an online, password-protected database. All statistical analyses were conducted using SAS statistical software (v 9.4; SAS Institute Inc, Cary, NC, USA). Demographic and clinical characteristics were assessed at baseline, where mean and standard deviation (SD) were used for continuous variables and frequencies and percentages for categorical variables. Data normality was checked by the Kolmogorov–Smirnov test and coefficients of skewness and kurtosis. Pre–post self-report standardized measures and performance measures were examined with paired sample *t*-tests for continuous data to detect significant changes over the course of therapy, and to determine possible differences in the participants lost to follow-up and the group that returned for posttesting.

Chi-square tests were used to compare frequencies between precategorical and postcategorical variables (eg, readiness for deployment). We have previously reported the significant correlation of the POWAR measures with the balance and mobility measures in ADSMs with mTBI as well as healthy control peers,[10] but here we analyze the change in these measures and their correlation with change on POWAR measures using Pearson correlation coefficients.

For self-report and performance-based measures, we characterized change in the entire sample across measures by computing within-subjects repeated-measures Cohen *d* effect sizes[27]:

$$d = \frac{m_{post} - m_{pre}}{\sqrt{s_{pre}^2 + s_{post}^2 - 2r \times s_{pre} \times s_{post}}} \sqrt{2\,(1 - r)}$$

where m_{pre}/s_{pre} and m_{post}/s_{post} are the means/SDs of the evaluated measure before and after the therapy, respectively; r is the Pearson correlation coefficient between the 2 sets of observations.

An anchor-based responsiveness assessment was performance based on creating 2 groups (Improved/Not Improved) based on self-reported posttest PGIC ratings. The PGIC is a measure that was developed by the TBI CoE to reflect overall improvement during a course of treatment and is recommended as an outcome measure for military mTBI research.[12,28]

Patients are asked to choose the best description of changes in activity limitations, symptoms, emotions, and overall quality of life since beginning physical therapy: “no change (or condition has gotten worse),” scored as 1; “almost the same, hardly any change at all,” scored as 2; “a little better, but no noticeable change,” scored as 3; “somewhat better, but the change has not made any real difference,” scored as 4; “moderately better, and a slight but noticeable change,” scored as 5; “better and a definite improvement that has made a real and worthwhile difference,” scored as 6; and “a great deal better and a considerable improvement that has made all the difference,” scored as 7.[12]

We determined a grouping of greater than or equal to 6 to characterize those who had meaningful improvement and PGIC scores of 5 and less to characterize those without meaningful improvement. Minimal clinically important differences (MCIDs) were calculated for POWAR motor performance based on individuals who rated PGIC at level 6–7. Minimal detectable changes (MDCs) were calculated for POWAR motor performance based on individuals who rated PGIC at ≤ 5, as we reasoned that the wording of the PGIC description for level 5 seemed consistent with definition of MDC, whereas levels 6–7 were more in line with a perception of MCID.

Test–retest reliability of the entire POWAR task was examined with a 2-way repeated-measures linear mixed effect model with absolute agreement (first vs second testing session, subject-by-subject variation). ICCs were calculated for POWAR metrics (single and DT condition stability of motor and cognitive tasks). A P value of $< .05$ was considered statistically significant.

Results

Pre–Post Therapy Testing

Demographic information for the 49 participants who returned for posttherapy testing is summarized in Table 1. The ADSM in this study had sustained their most recent concussion an average of 7.57 months prior to initial physical

Table 2. Self-Report, Performance, and POWAR-TOTAL Scores: Initial Test Lost to Follow-Up Group; Study Group Initial, Final, and Effect Size[a]

Measure	LTFU Group Mean (SD) $n = 25^b$	Initial Mean (SD) $n = 49$	Final Mean (SD) $n = 49$	P	Effect Size
NSI (0–88)	41.3 (19.1)	37.6 (15.1)	28.2 (16.9)	<.001	−0.58
PCL-C (0–80)	31.3 (20.4)	28.8 (20.1)	21.1 (18.9)	<.001	−0.39
DVPRS (0–10)	4.2 (2.2)	4.4 (2.0)	3.1 (2.2)	<.001	−0.62
DHI (0–100)	42.1 (21.5)	33.5 (20.0)	24.4 (19.7)	<.001	−0.46
HIT-6 (36–78)	60.5 (8.1)	62.3 (8.1)	57.4 (8.9)	<.001	−0.58
PSQI (>5 referral threshold)	12.9 (4.7)	13.5 (4.5)	11.1 (5.0)	<.001	−0.50
DVAT (lines lost) D(lines lost)	2.3 (1.2)	2.6 (1.5)	1.8 (1.0)	<.001	−0.71
SOT Composite (of 100)	68.5 (14.3)	68.6 (15.3)	75.7 (13.9)	<.001	0.72
HiMAT (of 32)	21.4 (7.3)	22.3 (8.1)	24.3 (7.6)	<.001	0.32
POWAR-TOTAL Metrics					
ST-Cognitive (of 8)	5.7 (2.1)	5.4 (1.9)	6.6 (1.5)	<.001	0.67
DT-Cognitive (avg of 3 trials, of 8)	5.1 (2.1)	5.2 (1.8)	5.9 (1.7)	0.003	0.42
ST-Motor (s)	17.7 (6.6)	16.1 (4.0)	14.3 (3.0)	0.002	−0.51
DT-Motor (avg of 3 trials, s)	16.8 (6.5)	15.9 (4.6)	14.0 (2.8)	0.006	−0.50
Pretest vision line	8.1 (1.3)[b]	7.4 (1.3)[b]	7.6 (1.2)	0.124	0.16
Pretest self-rated vision clarity	3.8 (2.1)	3.6 (2.1)	3.8 (2.2)	0.553	0.09
Posttest vision line	8.1 (1.0)[b]	6.8 (1.3)[b]	7.4 (1.5)	0.053	0.36
Posttest self-rated vision clarity	5.2 (2.1)	4.7 (2.4)	4.3 (2.1)	0.277	−0.18
Completed all trials	20 (80%)	47 (95.9%)	48 (98.0%)		

[a]DHI = Dizziness Handicap Inventory; DT = dual-task; DVAT = Dynamic Visual Acuity (noninstrumented version); DVPRS = Defense and Veterans Pain Rating Scale; HiMAT = High-level Mobility Assessment Test; HIT-6 = Headache Impact Test; LTFU = lost to follow-up; NSI = Neurobehavioral Symptom Inventory; PCL-C = Post Traumatic Stress Disorder Checklist-Civilian; PSQI = Pittsburgh Sleep Quality Index; SOT = Sensory Organization Test; ST = single task. [b]Significant difference in initial test values in the lost to follow-up group and the group that was tested before and following therapy. Visual acuity was rated on a Snellen chart with line 8 representing 20/20 vision. Visual clarity was rated on a 0–10 visual analog scale with 0 as "perfectly clear" and 10 "extremely blurry and/or unstable."

therapist evaluation, with a range of 1.45 to 23 months. They completed an average of 9.75 physical therapist visits, with a wide range from 1 to 44, that included 1:1 physical therapist sessions, home exercise program only format, and/or group-based therapy sessions. These participants were often also seeing other disciplines related to cognitive, visual, or behavioral health concerns. There was no attempt to standardize or control interventions, given our focus on the validation of the POWAR-TOTAL measure.

Physical therapist interventions were administered by the therapist who performed the evaluation. Examples include strategies to address cervical pain and stiffness, dizziness, vertigo, exertional intolerance, and balance problems. Study participants may have participated in individual and/or group physical therapist sessions. Additional treatments may have included aquatic therapy, yoga, vision rehabilitation, and cognitive and behavioral interventions provided by other rehabilitation specialists co-located at each ISC and based on individual needs and evaluation findings.

Following treatment, on average, self-reported measures (NSI, PCL-C, DVPRS, DHI, PSQI) reflected statistically significant improvements in their respective domains (Tab. 2). HiMAT total, SOT composite score, and DVAT lines lost following completion of therapy also improved, indicating higher level motor ability, static postural stability, and visual acuity with head movement. It is important to note that even though improvements occurred, they were not complete with some residual self-reported complaints.

Improvements were noted in POWAR-TOTAL results for ST and DT performance for both cognitive and motor tasks as well as visual acuity after exertion, but there were no differences in pretest visual acuity and clarity (Tab. 2). At both test sessions, average DT motor time was faster than ST motor time. DT cognitive score, measured as an average of 3 trials, was lower than the ST cognitive score. On average, ADSMs prioritized the motor component of the task over the cognitive.

POWAR motor performance (ST and DT conditions) was significantly inversely correlated to HiMAT, the measure we considered closest to a gold standard for assessing validity, (ST $r = -.55$; $P < .001$ [95% CI = −.72 to −.30]) (DT $r = -.37$; $P = .01$ [95% CI = −.60 to −.09]) in the complete sample ($n = 74$). To examine responsiveness, change scores for the POWAR motor task were correlated with changes in HiMAT, SOT, NSI, and DHI, given POWAR is intended to challenge vestibular and balance function (Tab. 3). HiMAT changes demonstrated the most significant correlations to changes in POWAR motor scores, followed by the SOT. The DHI, which is designed to identify complaints of dizziness, had higher correlation values than the more generic self-report measure, the NSI, supporting discriminant validity.

Effect sizes of the performance-based tests were all in the medium range (Tab. 2).

Anchor-based responsiveness was examined by comparing those who scored the PGIC at 1–4 (little to no change or worse) and those who scored the PGIC at greater than or equal to 5 (self-rated improvement). This analysis included a total

Table 3. Correlations in POWAR Motor Pre–Post Change to Change in Performance and Self-Report Measures for the Study Group[a]

Instrument	POWAR ST Motor (95% CI)	P	POWAR DT Motor (95% CI)	P
High-level Mobility Assessment Test	0.52 (0.26 to 0.71)	<.001	0.55 (0.29 to 0.73)	<.001
Sensory Organization Test	0.46 (0.16 to 0.67)	.004	0.42 (0.11 to 0.65)	.009
Neurobehavioral Symptom Inventory	0.35 (0.07 to 0.58)	.01	0.29 (−0.004 to 0.53)	.05
Dizziness Handicap Inventory	0.44 (0.17 to 0.64)	.002	0.30 (0.01 to 0.54)	.04

[a]DT = dual task; ST = single task.

of 47 participants who had complete data on all necessary measures. At posttesting, mean (SD) POWAR ST motor was significantly faster in those reporting improvement on the PGIC ($n = 31$; −2.87 [3.98] seconds) compared to those in the no change or worsening group ($n = 16$; 0.12 [3.14] points) ($P = .008$). POWAR DT motor was also significantly faster between those reporting improvement (−3.00 [5.08] seconds) and the group reporting no change or worsening averaging (−0.07 [3.01] seconds) ($P = .02$).

MCIDs were computed as the mean change in individuals who reported what we interpreted as significant change on the PGIC (levels 6 or 7, $n = 17$), resulting in an MCID of −3.65 seconds for ST motor and − 3.85 seconds for DT motor. Cognitive task performance was not significantly different in the 2 groups as sorted by PGIC. MDCs were computed based on individuals who reported a PGIC of ≤5, who reported only slight or no improvement after therapy ($n = 30$), resulting in an MDC of −1.96 seconds for POWAR ST motor and −2.05 seconds for POWAR DT motor.

Test–Retest Stability for ADSM Controls

Observational measures (hand timing, cognitive task scoring) for POWAR-TOTAL components for the 11 healthy control subjects improved on average on the second test for the motor task (by 0.82 and 1.06 seconds for single and DT conditions, respectively), but not the cognitive task. These improvements fall far short of the MDC (<52%) and MCID values (<28%). ICC values for the motor task were 0.88 for the ST condition and 0.84 for the DT condition. For the cognitive task, ICC values were 0.81 and 0.83 for the single and DT conditions, respectively.

Lost to Follow-Up Group Characteristics

The lack of treatment control in this study created challenges for engaging participants in posttesting. The scope and duration of therapy for individuals varied widely. Data collection for the study spanned from May 2018 to August 2020, including months in 2020 where the COVID pandemic caused suspension of research operations and halted intervention prior to transitions to telehealth. We collected data on 74 ADSM with concussion, but 25 of those participants were lost to follow-up, leaving 49 ADSM in the final analysis. The majority of individuals who were lost to follow-up ($n = 18$) did not respond to texts or calls to schedule a posttesting session, so reasons for lack of participation are unclear. Analysis of those lost to follow-up did not identify any group differences on demographics, self-reported, or performance-based measures with the exception of visual acuity, where those lost to follow-up had significantly better visual acuity at rest and following the POWAR test motor trials at their initial test session (Tab. 2).

Role of the Funding Source

The funder played no role in the design, administration, or reporting of the study.

Discussion

The development of the POWAR-TOTAL test was initiated by feedback from military therapists who expressed the need for higher level challenges that approximated the demands of military service.[8] Tests developed for use after concussion involve basic motor skill such as standing or walking, where test sensitivity beyond the acute period is limited.[28,29] These tests were developed initially to identify concussion occurrence and were commonly used to judge recovery after rest to improve symptoms by comparison to a preinjury baseline tests. The use of the baseline testing approach has come under question recently,[29] necessitating measures that can be used without a preinjury baseline. In recent years, there has been a shift from a "rest and recover" approach to mTBI to an active rehabilitation approach.[30] Measures developed as sideline assessments to identify concussion may not be ideal to monitor the effects of rehabilitation weeks or months postinjury.

Many physical therapist walking tests were developed for older adults with balance impairment and may have ceiling effects for ADSM.[31] The combination of motor and cognitive skill required in the POWAR-TOTAL test was intentional, as the assessment of motor or cognitive skill in isolation may miss subtle impairments evident in DT conditions.[32] Therapists choose assessments that relate to participation goals for their patients. It stands to reason that military therapists may need more complex measures for service members that go beyond standing and walking and resemble training activities to inform recommendations about return to duty. The POWAR-TOTAL is a test that could be used clinically as an additional tool for ADSMs in rehabilitation after mTBI.

ADSM performing the POWAR-TOTAL test demonstrated practice effects associated with learning the novel motor task, as DT test trials were faster than single task trials that preceded them. There was a DT interference effect demonstrated by poorer recall of the cognitive task in the DT condition compared with the single task condition. There was no explicit instruction about task prioritization during test administration; however on average, ADSM prioritized on the motor task. This prioritization is consistent with military culture that values physical performance at a high level.

Results of the study support the construct validity of the POWAR measure and its responsiveness to meaningful change that occurs over an episode of physical therapist care. POWAR has face validity in its similarity to skills commonly required of ADSM, can be conducted in typical clinical space, and takes less than 15 minutes to conduct. Within-person responsiveness was supported by medium effect sizes for POWAR-TOTAL variables.

Improvements in motor and cognitive performance following therapy were correlated with changes in other performance-based and self-report measures in the expected directions. External responsiveness of the measure was supported through the use of the PGIC as an anchor. Using PGIC anchor ratings, MCID and MDC values were calculated to provide *preliminary* interpretability guidance for clinicians, suggesting that improvements of 3.65 (ST) and 3.85 (DT) seconds are associated with clinically important change; and improvements of 1.96 (ST) and 2.05 (DT) seconds are necessary to conclude actual change has occurred. The extent of the practice effects of the test with a healthy control group was examined in a small subsample, but it suggests that practice effects are much smaller than MDC and MCID. Additional study of test–retest reliability in a larger sample of healthy controls and development of age and sex-related reference values is necessary to guide interpretation of test results in clinical practice.

Stronger correlations of ST POWAR measures to the HiMAT follow logically, as the ST condition has a sole focus on motor performance. The introduction of the dual-task condition requires attention to be allocated to 2 tasks, but detailed analysis of POWAR DT performance is beyond the scope of this paper. The POWAR motor task could be used without the DT condition to shorten testing time, as single and DT motor task metrics were similar in their relation to concurrent measures. Pre–post therapy effect size for the HiMAT for the patient group was small, whereas effect sizes for POWAR components were moderate, suggesting it may be more useful in capturing change in higher level mobility in this population.

This testing protocol included visual acuity and clarity testing prior to and following the POWAR-TOTAL test trials. Within initial test sessions, visual acuity and clarity showed a significant decline after completion of the ST and DT motor trials when compared to pretest status, reflecting the impact of the agility task on vision and suggesting that the effects of concussion on vestibulo-ocular function may not be apparent at rest. Dynamic challenge of the vestibular system may be particularly important to critical soldiering skills, such as marksmanship while maneuvering. No significant differences in resting visual acuity or clarity were observed following physical therapist intervention. This may indicate a true lack of change in static visual acuity or an inability of our basic measures to detect subtle changes.

Limitations

Individuals enrolled in this study were on average more than 7 months postinjury; therefore, the utility of this test for more acute concussion is not clear. Individuals with mTBI may have a range of impairments including cognitive function, oculomotor issues, and vestibular impairments that were not comprehensively assessed in our study protocol that may have contributed to performance differences in this group. However, a measure that examines multiple capacities at once in a functional context could be an efficient clinical approach.

In the military health system, concussion is often managed by primary care, and many who sustain this injury may be guided back to full activity without the need for specialized rehabilitation.[2] Individuals referred for therapy at ISCs may have more complex initial injuries, a history of prior concussions, or other comorbidities that cause them to seek care, and some may not intend to remain in active-duty service. Referral for multidisciplinary rehabilitation may be delayed as a result of multiple factors including military cultural norms. This population may therefore be quite different from civilians seen for sport concussion, where recovery may be rapid and complete with limited intervention.

The POWAR-TOTAL measure was designed to challenge physical impairments that were the focus of physical therapy and test skills in combination versus separately. On average, participants showed improvement on self-report and performance measures, but residual complaints of pain, headache, and sleep disturbance remained. Some of the participants continued treatment as part of the multidisciplinary treatment process that is administered through the ISCs. We are unable to determine if residual complaints were completely resolved after all treatment ended, but it is possible that some individuals who sustain mTBI do not recover completely prior to return to active duty.

Study examiners were not blind to group status in the larger study, which may have induced bias; however, data were measured using a stopwatch, inertial sensors, and verbatim recording of verbal responses. Therefore, the influence of bias on results is likely to be low. During initial testing, 7 participants did not complete the entire POWAR test protocol because of participant requests to stop because of onset of increased symptoms ($n = 4$) or by project staff because of concerns for symptom increase or safety ($n = 3$). Of the ADSM who could not complete the entire POWAR test battery at baseline, 4 were lost to follow-up, but 3 returned for posttesting and were able to complete all trials. The floor effect (9.5%) observed in initial testing could discourage those who are very symptomatic in their recovery and may have influenced their return for posttesting. However, examination of self-report and performance measures did not indicate significant differences in the lost to follow-up group and those who returned for posttesting, with the exception of self-reported visual ratings, which were better in those lost to follow up (Tab. 2). The timing of the initial assessment was in the first week of an episode of physical therapist care, when symptom burden of some individuals was high. If this test is used in clinical practice, the therapist could use the test when symptoms have stabilized, and preparing for a return to full duty is a focus of treatment.

The POWAR motor task was devised to challenge the vestibular system; however, participants in this study were receiving physical therapy for other reasons that may or may not have had a vestibular etiology. Performance-based measures that target other areas (eg, exertion or cervicogenic impairment) may be needed to evaluate ADSMs and inform providers about overall recovery and physical readiness for return to duty. Enrollment of participants in physical therapy may have excluded individuals with subtle impairments who were seen by the ISC physical therapists for evaluation only and physical therapist interventions were not recommended.

The PGIC is a measure that is advocated for use in military mTBI research, but is complex in its targets encompassing global quality of life and it refers to "your painful condition." Although there are versions of the scale that instead reference "your post concussive condition" that might have better captured targets of physical therapy, we used the version that mentions pain, shared by the TBI CoE site.[2] Pain is a common complaint in ADSM. On average, the self-reported DVPRS level reduced from 4.4 (4 = distracts me, can do usual activities, 5 = interrupts some activities) to 3.1 (3 = sometimes distracts me) in the sample who returned for testing. Participants were not excluded if they had pain or musculoskeletal impairments that could also affect performance of the task. It is possible that physical therapy was instead focused on impairments not related to pain, making this measure less applicable for some enrolled in the study. Physical function is clearly an important factor in quality of life for an ADSM, but many other factors could also influence responses to the PGIC question, reducing its value as an anchor for our study.

Only ADSM ratings on the PGIC were recorded. We did not collect provider impressions of improvement that would have provided an additional anchor-based method of evaluation. A question more focused on functional recovery may provide a better self-report anchor when evaluating measures that are physical performance-based. The timing of post–physical therapist testing did not necessarily coincide with conclusion of all rehabilitation, as participants may have also been receiving services for headache, behavioral health conditions, visual impairments, or cognitive impairments that also influenced response to the PGIC, perception of quality of life, and ability to fully return to active duty.

Conclusion

The POWAR-TOTAL captured improvements in high-level mobility after an individualized outpatient physical therapist treatment program targeting impairments that were related to concussive injury. Reliability of the measure is acceptable. Construct validity is supported by correlation with concurrent measures, discriminant validity is supported with the analysis of change scores, and responsiveness to change of the measure is promising. The POWAR-TOTAL is an additional clinical tool for providers who inform return-to-duty decisions. The test incorporates tasks that are military specific and addresses a range of vulnerabilities known to be affected by mTBI that may be useful in military contexts when rehabilitation is undertaken beyond the acute period postinjury. The motor task may have utility used on its own or in the DT conditions used in this study. Ensuring the fighting force is sufficiently recovered after an mTBI will aid in supporting individual and unit readiness for effective mission capability. Additional study will provide more refined guidance for interpretation of scores and timing of the use of POWAR-TOTAL in clinical practice.

Author Contributions

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Ethics Approval

The study received approval from the Regional Health Command-Atlantic and MAMC Institutional Review Boards.

Data Availability

Data from this project are uploaded in FITBIR, https://fitbir.nih.gov/portal/study/viewStudyAction!view.action?studyId=FITBIR-STUDY0000379.

Disclosures

The authors completed the ICMJE Form for Disclosure of Potential Conflicts of Interest and reported no conflicts of interest.

The opinions, interpretations, conclusions, and recommendations are those of the author and are not necessarily endorsed by the Department of Defense.

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