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14. ABSTRACT The primary objective of this 2-year project is to further refine and conduct preliminary validation of a novel set of test-tasks known as the Assessment of Military Multitasking Performance (AMMP). The AMMP is a battery of functional dual- and multi tasks that simulate the combined sensorimotor, cognitive, and exertional demands of Soldiering for use after concussion/mild traumatic brain injury (mTBI). Task evaluation criteria including inter-rater reliability and total test time findings are being used to refine the task battery. Using healthy control subjects, dual-tasks have shown excellent inter-rater reliability; while ongoing refinement of task instructions and scoring has improved multitask reliability. All regulatory approvals have been obtained and data collection in both healthy control and SM with mTBI has begun at Fort Bragg/Womack Army Medical Center in order to determine preliminary construct and discriminate validity of the AMMP. Investigators anticipate that once validated, the AMMP will discriminate between "duty-ready" and "non-duty ready" military Service members (SM) following mTBI and will be used in combination with other metrics to inform duty-readiness decisions.					
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Annual Report
The Assessment of Military Multitasking Performance: Validation of a Dual-Task and Multitask Protocol (Contract W81XWH-12-2-0070)

INTRODUCTION: The primary objective of this 2-year project is to further refine and conduct preliminary validation of a novel set of test-tasks known as the *Assessment of Military Multitasking Performance* (AMMP). The AMMP is a battery of functional dual- and multi tasks that simulate the combined sensorimotor, cognitive, and exertional demands of Soldiering for use after concussion/mild traumatic brain injury (mTBI) (Radomski et al 2013). Investigators anticipate that once validated, the AMMP will discriminate between “duty-ready” and “non-duty ready” military Service Members (SM) following mTBI and will be used in combination with other metrics to inform duty-readiness decisions. It is further expected that a validated AMMP will contribute much needed objectivity to the current return to duty (RTD) determination process (Scherer et al., 2013). We anticipate that future studies will inform how the AMMP can be leveraged in combination with other psychological, physical, demographic and soldiering metrics to develop a clinical prediction rule for recommendations on RTD in SM with mTBI exposure.

BODY:

Aims of the proposal as described in the SOW are:

Aim 1: Further specify and refine a set of dual and multitasks with procedures for test administration.

Approach: Task refinement, preliminary retest reliability and scoring testing at SKRC in healthy control SM and SM with mTBI symptom complex. Reliability testing at US Army Research Institute of Environmental Medicine (USARIEM) (and/or US Army Aeromedical Research Laboratory (USAARL)) among healthy control SM will further delineate tasks that meet evaluation criteria (**see Table 1 on Task Evaluation Criteria**). Tasks that do not meet feasibility or reliability specifications will be dropped or revised. Test-task evaluation will continue throughout the 2-year study to examine ability to discriminate SM with and without mTBI symptom complex. Correlations with neurobehavioral testing of known mTBI vulnerabilities (components of ANAM, dynamic visual acuity, tests of selective attention, processing speed and working memory) will be confirmed. Final determination of tasks that remain in the AMMP and the means to combine scoring into a single or multiple metrics will be determined in consultation with test development experts throughout the 2 year project.

Progress toward Aim 1: Task evaluation is an ongoing process using the criteria in the Task Evaluation Criteria Table (Table 1) which up to this point have included primarily test burden including test time, and inter-rater reliability findings as described below under Aim 2. Prefunded pilot work on healthy control civilians and members of the Minnesota National Guard have been conducted at the Sister Kenny Research Center. Availability of volunteers from the MN Guard and Minneapolis VA Health Care System has been limited, mainly due to changes in the patient population being treated at the VA. All data on healthy control subjects has been obtained via volunteers from USARIEM in Natick, MA. Studies at Fort Bragg/Womack Army Medical Center in Fayetteville, NC received all regulatory approvals in August 2013. Data collection on subjects with mild traumatic brain injury was initiated at WAMC /Fort Bragg also in August 2013 with the initial 7 subjects. We expect data sufficient for planned analysis to be collected over the next 10-11 months.

Table 1: Task Evaluation Criteria

Parameter	Description
1. Total time, set up, take down	Time
2. Storage space	Square feet

3. Objective scoring	Scoring can be constructed to be objective
4. Dimension(s) challenged	Which of the dimensions are challenged by the task
5. Time to give instructions	Time from beginning instructions to participant beginning the task
6. Participant's evaluation of task	Questionnaire to obtain feedback about performance of the task(s)
7. Inter-rater reliability	Minimum of 0.85 on observations of complex task assessments. Minimum of 0.90 for dual-task assessments.
8. Convergent/discriminant validity	Correlations between task scores and hypothesized related tests of common domain scores will be significant (non-zero) and not less than 0.40.
9. Known groups construct validity	Significant differences between healthy controls and SM with mTBI complex symptoms at a p-value <0.05 and a minimum effect size of 0.5.

Aim 2: Evaluate inter-rater for each of the dual- and multitasks using healthy control and SM with diagnosed mTBI.

Approach: Inter-rater reliability and assessment of training requirements for expert and novice raters will be completed using 20-25 Human Research Volunteers and permanent party personnel at USARIEM. We anticipate that several test-tasks that do not meet evaluation criteria (see **Table on Task Evaluation Criteria**) will be eliminated from the protocol based on initial testing. This will decrease testing time and burden in subsequent data collection. At Fort Bragg/Sister Kenny Research Center (SKRC) 80 healthy control and 80 SM with mTBI will be tested using the scaled down AMMP. We will assess order effects based on observation of performance as well as actual task scores in the Fort Bragg/SKRC testing cohorts. Inter-rater reliability of the AMMP will be evaluated in a subset of SM with mTBI at Fort Bragg. Measures of fatigue (to evaluate test burden) and malingering are planned. Where feasible, test-retest reliability for several of the tasks is being assessed during current task evaluation trials at UNC and SKRC (Winter/Spring 2012). Retest reliability for the multitasks would require parallel forms of the tasks and this will be addressed in future validation trials.

Progress toward Aim 2:

- USARIEM IRB protocol approved and data collection completed for 20 active duty Service members (SM) for the inter-rater reliability study conducted at USARIEM from 27 November through 4 December 2012. Table 2 provides a summary of the findings on the inter-rater reliability for the 9 original AMMP tasks tested, as well as a brief description of the recommended revisions based on findings and the task evaluation criteria described in Table 1.
- USARIEM data collection completed for additional inter-rater reliability testing for 12 active duty SM on 3 revised AMMP test tasks on 1May through 3May2013. Data has been analyzed and the changes incorporated into the scoring forms and instructions for the revised tasks in preparation for Fort Bragg data collection. Table 3 provides a summary of the findings on the inter-rater reliability for the 3 revised AMMP tasks tested, as well as a brief description of the recommended revisions based on findings and the task evaluation criteria described in Table 1.
- Final closure report for this protocol was submitted to USARIEM HURC and accepted 4June 2013. Final closure report on this protocol in process for Allina IRB.

The specific objectives for the studies completed at USARIEM were:

1. Obtain preliminary inter-rater reliability of the AMMP tasks in a sample of healthy control SM volunteers.
2. Assess feasibility and test burden on SM to perform the AMMP test battery (include neurobehavioral, and survey/fatigue measures) using post-test surveys and informal interviews of subjects.

Table 2: Inter-rater reliability (IRR) findings/ USARIEM -- 20 Healthy controls (HC) Nov/Dec 2012

Task Type	AMMP Task	Reliability (ICC) Range for all scoring items per task	Recommended Revisions
Dual Tasks	Load Magazine / Radio Chatter	0.93-0.99	No revisions except making sure subject is facing raters to allow hearing of vocal response
	Instrumented Stand & Walk / Grid Coordinates	0.56-0.99	Only 1 scoring item showed IRR below 0.92 (otherwise 0.92-0.99) due to scorers difficulty hearing SM state Grid Coordinates from behind, modified test position to correct
	Illinois Agility / Word List	0.89-1.0	Revision of word lists to change items not familiar to some SM and to decrease 2 word items. Clarify errors in agility path versus errors in word list recall to improve IRR.
	Step Initiation / Stroop	Instrumented, reliability not measured	Task deleted, least face validity, time constraints. Functional Reaction time component inserted into SALUTE with exertion task
Multitasks	A-bag packing	0.19-0.55	Tasks revised and merged due to issues with poor reliability and test time burden. Development of new task called CQ Duty to include most reliable scoring metrics of these tasks; Retested at USARIEM May 2013
	Duty Roster	0.40-.096	
	Pack Ship	0.30-0.99	
	SALUTE with exertion	Total score 0.80 Subcomponents .29-.99	Revisions of scoring instructions and scoring sheet, provision of examples on score sheet, revision of SALUTE video. Retested at USARIEM May 2013
	Run-Roll-Aim	0.89-1.0	Corrected descriptions of errors versus cues to enhance rater reliability. Revised scoring sheet.

HC=Healthy Controls; SM=Service member

Inter-rater reliability

- The Krippendorff Alpha (Hayes 2007) was used to evaluate inter-rater reliability. This general measure can be used regardless of the number of observers, sample size, missing data and type of

measurement (nominal, ordinal, interval, or ratio). For both interval and ratio data the analysis is equivalent to the intraclass correlation coefficient (ICC) for two observers and is extended for many observers. For nominal data, analysis for two observers is equivalent to Scott's Pi. Parallel analyses using both the Krippendorff and Kappa (2 observers) have produced identical results. The code was integrated into SPSS V18.0. Bootstrapping using an n=2000 was used to produce 95% confidence intervals.

- In some cases where the scorers were not constant the SPSS V18.0 ICC analysis using the two-way random model was used to confirm the Krippendorff result.
- For items that required a yes/no response, number of triplet scorings with disagreement in scores was completed though not shown in this report. Given that a full range of combinations of responses did not occur, a Kappa like analysis was not possible.
- For low ICCs further analysis of paired scorers was completed to discover reasons for reliability errors (not shown in this report).

Limitations

Inter-rater reliability calculations are highly sensitive to the range of possible values. For items that take on values such as 0 to 5, differences between scorers will affect the calculation greater than values that are continuous such as time or total number of tasks completed that have high maximum values. This is due to the distance between values relative to the range.

Due to this sensitivity, sub-task groupings as is used for several multitasks may have low IRR while the total IRR is acceptable. This supports the need to evaluate sub-group scores and perhaps even item by item evaluation may be necessary where a large number of observations are required.

Table 3: Inter-rater reliability findings/ USARIEM -- 12 Healthy controls (HC) May 2013

Task Type	AMMP Task	Reliability (ICC) Range for all scoring items per task	Recommended Revisions
Multitask	SALUTE with exertion	Total score 0.79 Subcomponents .14-.99	Continues to be an issue with inter-rater reliability of subcomponents partially due to the limited range (total subcomponent max score of 2 (range 0-2). Definitions and scoring examples for each line (Sierra, Alpha, etc.) revised. Will retest at Fort Bragg.
	CQ Duty	0.64-0.98	Rule break scoring was not reliable due to lack of clarity in definition. Definitions revised. Will retest at Fort Bragg.
	Militarized Modified 6 Elements Test	0.62-1.0	New task developed from 6 Elements test (*Wilson et al 1996), shows potential as quick evaluation of executive function that appears feasible for deployed environments. Noted to have insufficient time allotted for training of raters which is believed to have affected reliability. Have modified training

			protocol, and additional reliability testing will be completed at Fort Bragg following approval of submitted (20Aug2013) amendment.
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*Behavioral Assessment of the Dysexecutive Syndrome, Wilson, B.A., Alderman, N., Burgess, P.W., Hazel, E., Evans, J.J. (1996). Pearson Assessment.

Implications: As a result of test reliability and feasibility findings, Test Tasks Pack-Ship, Duty Roster and A-Bag were removed from the battery based on poor inter-rater reliability and prolonged test administration time criteria. In their place, the CQ task and the Militarized Modified Six Elements task were added. Both appear to have improved reliability and average test administration time. Test task SALUTE V2 has comparable IRR to the SALUTE V1 task ($r = 0.79$ and $r = 0.80$ respectively) however, with the addition of a visual scanning task with the newest SALUTE video (V2) provides information on visual memory and may prove more reliable with subtle modifications in scoring rules and test instructions.

Results from the neurobehavioral post-test measure of fatigue suggest that there was no significant degradation in simple reaction time that would suggest participant fatigue (Table 4). Simple reaction time was tested before beginning the AMMP task battery, half way through the task battery and at its completion. Post-test interviews and participant surveys yielded no additional indication that the AMMP battery resulted in perceived or actual elevation in fatigue levels given the 3 ½ to 4 hour test burden.

Table 4: Simple Reaction Time as Measure of Fatigue Findings/USARIEM, 20 Healthy Control, Nov/Dec 2012

Baseline (mean(SD))	283.6(49.4)
Midway(mean(SD))	267.8(22.0)
End(mean(SD))	269.2(22.2)
p-values	
Baseline-Midway	0.12
Baseline-End	0.14
Midway-End	0.73

Overall, Aims 1 and 2 for these studies at USARIEM (Nov/Dec 2012 and May 2013) were both met. Total test burden for the battery was approximately 4 hours when neurocognitive testing was included. Investigators appreciate that the test burden most appropriately should not exceed 2 hours, possibly 2 ½ hours, if the AMMP battery is to be considered feasible for use in a clinical environment. Refining the test burden down to two hours is the goal for the next phase of testing anticipated at Fort Bragg which began in August 2013. The team used the reliability and feasibility data collected in the USARIEM protocol to make additional determinations regarding test battery composition and revisions to scoring forms, scoring training and instruction for the Fort Bragg/Womack Army Medical Center phase of the project.

Aim 3: Determine correlation between scores on neurobehavioral and sensorimotor domain tests and scores on AMMP dual- and multitasks in healthy control SMs and SM with mTBI.

Approach: Preliminary evaluation of construct validity will be performed by determining correlations between neurobehavioral and sensorimotor tests of known mTBI vulnerabilities (e.g., clinical tests of selective attention, processing speed, working memory, executive function and dynamic visual acuity [see **Table of Test Tasks & Neurobehavioral domains**]) and individual AMMP tasks in SM with and without mTBI. Testing will be performed at Fort Bragg and SKRC with a total of 80 SM in each group (healthy control [HC] and mTBI).

Progress toward Aim 3: Studies at Fort Bragg/Womack Army Medical Center (WAMC) in Fayetteville, NC received all regulatory approvals in August 2013. Data collection on subjects with mild traumatic brain injury was initiated at WAMC /Fort Bragg also in August 2013, with the initial 7 subjects. Additional data collection events for both healthy control and subjects with mTBI are scheduled over the next 10-11 months, with the planned data analysis to follow.

Aim 4: Determine ability of dual-task and multitask test items to discriminate between healthy control SM and SM with mTBI symptom complex.

Approach: A known groups comparison will be used to evaluate the ability of individual AMMP tasks to discriminate between 80 HC SM and 80 SM with diagnosed mTBI symptom complex. Testing will be completed in concert with Aim 3 at Fort Bragg and SKRC. Estimates of anticipated effect sizes for determining sample size have been determined from available literature (see **Table of Sample Size calculations**) and drive our hypothesized minimum effect size of 0.5.

Progress toward Aim 4: Studies at Fort Bragg/Womack Army Medical Center in Fayetteville, NC received all regulatory approvals in August 2013. A research coordinator and research assistants are in place, and data collection on subjects with mild traumatic brain injury was initiated at WAMC /Fort Bragg also in August 2013. Additional data collection events for both healthy control and subjects with mTBI are scheduled over the next 10-11 months, with the planned data analysis to follow.

KEY RESEARCH ACCOMPLISHMENTS:

- All regulatory approvals received, data collection completed and analyzed and project closure approvals completed for studies at US Army Institute of Environmental Medicine on inter-rater reliability and test burden of the AMMP battery in volunteer healthy control Service members.
- Ongoing development of a standardized AMMP administration manual to assure consistent data collection procedures and to develop preliminary task administration and rater training protocols.
- All regulatory approvals received, and initial data collection session completed for testing at WAMC/Fort Bragg. Following assessment of inter-rater reliability of AMMP test tasks in 20 subjects with mTBI, over the course of Year 2 of this project, testing will be performed at Fort Bragg/WAMC with a total of 80 SM in each group (healthy control and mTBI).

REPORTABLE OUTCOMES:

- 1) Returning Service Members to Duty Following Mild Traumatic Brain Injury: Exploring the Use of Dual- and Multitask Assessment Methods, Matthew R Scherer, PT, PhD, NCS, U.S. Army Research Institute of Environmental Medicine, Natick MA; Karen L. McCulloch PT, PhD, NCS, University of North Carolina, Chapel Hill, NC, ORISE Fellow Office of the Surgeon General.

Abstract accepted for presentation 2013 AMSUS Conference (The Society of Federal Health Professionals), 6 November 2013, Seattle, WA.

- 2) Radomski MV, Weightman MM, Davidson LF, Finkelstein M, Goldman S, McCulloch KL, Roy TC, Scherer M, Stern EB,. Development of a Measure to Inform Return-to-Duty Decision Making after Mild Traumatic Brain Injury. *Military Medicine*, 178(3):246-253, 2013. **NOTE:** this paper is primarily based on findings from prior funding from US Army Medical Research Materiel Command (W81XWH-09-2-0149) in support of development of the AMMP battery.
- 3) Matthew R. Scherer, Margaret M. Weightman, Mary V. Radomski, Leslie F. Davidson, Karen L. McCulloch; Returning Service Members to Duty Following Mild Traumatic Brain Injury: Exploring the Use of Dual-Task and Multitask Assessment Methods. *Physical Therapy Journal*, Sept 2013, 93(9):1-14.
- 4) **Works in preparation or submitted (awaiting acceptance):**
 - Manuscript in preparation for *American Journal of Occupational Therapy* with anticipated submission for military focus special issue in September 2013 and tentative title: "Preliminary Inter-Rater Reliability Findings for Military Multitasking Assessment: CQ Duty", Smith L, Radomski MV, Davidson L, Scherer M, et al., 2013.
 - 2014 American Physical Therapy Associations Conference and Exposition, 11-14 June, 2014, Charlotte, NC. Abstract submitted for Educational Session-1.5 Hours-Multiple Level, Military Topics: Civilian and Military Research Partnership: Methods for Success in Planning Research with Active Duty Military Participants. K.L. McCulloch, Division of PT, Dept of Allied Health Sciences, UNC-Chapel Hill, Chapel Hill, North Carolina; H. McMillan, Department of Brain Injury Medicine, Womack Army Medical Center, Fort Bragg, Fayetteville, North Carolina; M. Scherer, US Army Institute of Environmental Medicine, Natick, Massachusetts; A.S. Cecchini, Advanced Physical Therapy, Fayetteville, North Carolina.
 - 2014 American Physical Therapy Associations Conference and Exposition, 11-14 June, 2014, Charlotte, NC. Abstract submitted for Educational Session-1.5 Hours-Multiple Level, Military Topics: Return to Duty After Military Traumatic Brain Injury: Combined Physical and Cognitive Assessment Approaches Under Consideration at Fort Bragg, K.L. McCulloch, Division of PT, Dept of Allied Health Sciences, UNC-Chapel Hill, Chapel Hill, North Carolina; H. McMillan, Department of Brain Injury Medicine, Womack Army Medical Center, Fort Bragg, Fayetteville, North Carolina; M. Scherer, US Army Institute of Environmental Medicine, Natick, Massachusetts.

CONCLUSION:

A research team of military and civilian physical and occupational therapists is working to refine and develop preliminary validation data on a set of novel test-tasks which are part of the Assessment of Military Multitasking Performance (AMMP) that is anticipated to be used in combination with other metrics to inform duty-readiness decisions for Service members following mTBI. Inter-rater reliability findings from healthy control Service member volunteers from USARIEM demonstrate excellent reliability for dual-tasks. Task modifications were made based on test burden and inter-rater reliability findings for AMMP multitasks and further reliability testing is ongoing at Fort Bragg. All regulatory approvals have been obtained and data collection in both healthy control and SM with mTBI has begun at Fort Bragg/Womack Army Medical Center in support of the aims of this project. Dissemination efforts on the progress of this work have been initiated.

REFERENCES:

- 1) Radomski MV, Weightman MM, Davidson LF, Finkelstein M, Goldman S, McCulloch KL, Roy TC, Scherer M, Stern EB,. Development of a Measure to Inform Return-to-Duty Decision Making after Mild Traumatic Brain Injury. *Military Medicine*, 178(3):246-253, 2013.
- 2) Matthew R. Scherer, Margaret M. Weightman, Mary V. Radomski, Leslie F. Davidson, Karen L. McCulloch; Returning Service Members to Duty Following Mild Traumatic Brain Injury: Exploring the Use of Dual-Task and Multitask Assessment Methods. *Physical Therapy Journal*, Sept 2013, 93(9):1-14.
- 3) Behavioral Assessment of the Dysexecutive Syndrome, Wilson, B.A., Alderman, N., Burgess, P.W., Hazel, E., Evans, J.J. (1996) Pearson Assessment.

APPENDICES:

- 1) Returning Service Members to Duty Following Mild Traumatic Brain Injury: Exploring the Use of Dual- and Multitask Assessment Methods, Matthew R Scherer, PT, PhD, NCS, U.S. Army Research Institute of Environmental Medicine, Natick MA; Karen L. McCulloch PT, PhD, NCS, University of North Carolina, Chapel Hill, NC, ORISE Fellow Office of the Surgeon General. Abstract accepted for presentation 2013 AMSUS Conference (The Society of Federal Health Professionals), 6 November 2013, Seattle, WA.
- 2) Radomski MV, Weightman MM, Davidson LF, Finkelstein M, Goldman S, McCulloch KL, Roy TC, Scherer M, Stern EB,. Development of a Measure to Inform Return-to-Duty Decision Making after Mild Traumatic Brain Injury. *Military Medicine*, 178(3):246-253, 2013
- 3) Matthew R. Scherer, Margaret M. Weightman, Mary V. Radomski, Leslie F. Davidson, Karen L. McCulloch; Returning Service Members to Duty Following Mild Traumatic Brain Injury: Exploring the Use of Dual-Task and Multitask Assessment Methods. *Physical Therapy Journal*, Sept 2013, 93(9):1-14.

AMSUS 2013 ABSTRACT:

Returning Service Members to Duty Following Mild Traumatic Brain Injury: Exploring the Use of Dual- and Multitask Assessment Methods

Matthew R Scherer, PT, PhD, NCS, U.S. Army Research Institute of Environmental Medicine, Natick MA; Karen L. McCulloch PT, PhD, NCS, University of North Carolina, Chapel Hill, NC, ORISE Fellow Office of the Surgeon General

Within the last decade, over 220,000 Service Members (SM) have sustained Traumatic Brain Injury (TBI), many with complex co-morbidities, in support of military operations in Iraq and Afghanistan. Mild TBI may result in subtle cognitive and sensorimotor deficits that adversely affect Warfighter performance, creating significant challenges for SM, Commanders and medical providers. In the current conflicts, physical therapists have played an important role in evaluating SM readiness to return-to-duty (RTD). Incorporating research and best practices from the sports concussion community, military providers are increasingly adopting a sports medicine model to manage “tactical athletes” in operational environments. Because pre-morbid (baseline) performance is not typically available for deployed SM as it may be for athletes, clinicians determine duty readiness based upon the absence of post-concussive symptoms and return to “normal” performance on clinical assessments not yet validated among Warfighters. While similar practices described within the sports concussion literature guide “return to play” determinations, resolution of symptoms or improvement of isolated impairments may be inadequate to predict readiness in a military operational environment. Existing clinical metrics informing RTD decision-making are limited as they fail to emphasize functional, Warrior Task demands and lack versatility to assess the effects of co-morbid deficits. Emerging research efforts aim to address this discrepancy by developing challenging, realistic, and “standards-based” criteria to verify operational competence. Dual- and multitask methods have been described previously for the evaluation of sensorimotor and cognitive function following TBI. These show promise for approximating the complex operational demands of warfighting and guiding RTD decision making.

Key Words: Traumatic Brain Injury, Outcomes Assessment, Sensorimotor Performance

3 Objectives for the 6 November 2013 talk:

Upon conclusion of this 45 minute presentation, the learner will be able to successfully:

- 1) Identify common clinical symptoms and signs (neurocognitive or sensorimotor) associated with concussion/ mTBI in an operational setting.
- 2) Identify three or more limitations associated with current “standard of care” return to activity (i.e., “play” or “duty”) standards.
- 3) Recognize advantageous characteristics of dual- or multitask testing techniques for the determination of duty readiness in concussed SM.

ORIGINAL ARTICLES

Authors alone are responsible for opinions expressed in the contribution and for its clearance through their federal health agency, if required.

MILITARY MEDICINE, 178, 3:246, 2013

Development of a Measure to Inform Return-to-Duty Decision Making After Mild Traumatic Brain Injury

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ABSTRACT Mild traumatic brain injury (mTBI), a principal injury of the wars in Iraq and Afghanistan, can result in significant morbidity. To make accurate return-to-duty decisions for soldiers with mTBI, military medical personnel require sensitive, objective, and duty-relevant data to characterize subtle cognitive and sensorimotor injury sequelae. A military-civilian research team reviewed existing literature and obtained input from stakeholders, end users, and experts to specify the concept and develop a preliminary assessment protocol to address this need. Results of the literature review suggested the potential utility of a test based on dual-task and multitask assessment methods. Thirty-three individuals representing a variety of military and civilian stakeholders/experts participated in interviews. Interview data suggested that reliability/validity, clinical feasibility, usability across treatment facilities, military face validity, and capacity to challenge mission-critical mTBI vulnerabilities were important to ultimate adoption. The research team developed the Assessment of Military Multitasking Performance, a tool composed of eight dual and multitasking test-tasks. A concept test session with 10 subjects indicated preliminary face validity and informed modifications to scoring and design. Further validation is needed. The Assessment of Military Multitasking Performance may fill a gap identified by stakeholders for complex cognitive/motor testing to assist return-to-duty decisions for service members with mTBI.

INTRODUCTION

From 2000 through the third quarter of 2011, 229,106 individuals in the Armed Services have been diagnosed with a traumatic brain injury, with over 75% of these injuries classified as "mild."¹ Service members (SMs) with mild traumatic brain injury (mTBI), also referred to as concussion, may present with

an array of multisystem, overlapping symptoms that affect ability to perform military duties. These often include headache, dizziness, imbalance, nausea and vomiting, sleep disturbances, sensitivity to noise and light, slowed thinking and reaction time, memory problems, difficulty concentrating, executive dysfunction, and visual changes.² SMs who sustain mTBI may also experience visual-vestibular symptoms (e.g., vertigo, gaze instability, and motion intolerance)³ and emotional reactions.⁴

Symptom identification and monitoring after mTBI are important to both medical management and decision making regarding readiness to resume normal activities.⁵ SMs with suspected mTBI must be removed from combat or physically demanding duty until they are symptom-free^{6,7} for many reasons. First, cognitive and sensorimotor consequences of mTBI may threaten Warfighter proficiency and thereby the safety and effectiveness of the unit and their mission. Second, SMs with mTBI who incur a second concussion during acute recovery from a first injury may be at risk for prolonged cognitive recovery.⁸ Furthermore, symptom identification and monitoring guide referrals to higher levels of medical

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and/or rehabilitative care. In addition to treating mTBI-related symptoms, medical professionals are often asked to conduct exertional testing and determine when the SM demonstrates adequate symptom resolution to permit safe return to duty. It is important to note, however, that symptom resolution and clinical recovery may not reflect true neurophysiological recovery; SM with mTBI may still be in a period of neurological vulnerability.⁹

Given the above, current theater policy was established to standardize the evaluation and management of clinical concussion so that all SMs involved in a potentially concussive event are screened, temporarily removed from the battlefield to facilitate recovery, and provided a mandatory medical evaluation.⁶ At lower echelons, the algorithms provide clear guidance to Combat Medics, Corpsmen, and primary care providers on acute concussion evaluation. Medical care standards specify command and medically directed rest, early identification of red flags that signify need for evacuation, patient education, and initial symptom management. Centers devoted to concussion care in Afghanistan have established return-to-duty protocols that are largely modeled after those for return-to-play after sports-related concussion. However, these protocols lack objective, evidence-based, return-to-duty criteria. A given SM's readiness for duty in deployed environment is a clinical decision informed by the following: his or her report of symptom resolution; neurological and physical examination findings; whether or not symptoms can be elicited following exertional testing; and results of balance testing, a functional assessment, and/or a postinjury neurocognitive assessment (if available).

Methods and measures currently used to specify symptom resolution and readiness for return to duty are problematic for many reasons, including their reliance on self-reports.^{10,11} This is of particular concern as many SMs with mTBI minimize or do not report symptoms at the time of injury,¹² possibly because they desire to stay with their unit and remain in combat. At present, clinical biomarkers that could potentially specify neurometabolic recovery involve experimental neuroimaging approaches that are still under investigation and lack clinical feasibility.¹³ In addition, there is no consensus regarding the use of neuropsychological assessment in understanding mTBI-related impairment.¹⁴ It is also unclear which neuropsychological tests, if any, strongly predict real-world functioning after mTBI.¹⁵ Neuropsychological tests generally assess isolated cognitive skills and abilities,¹⁴ which match neither the multisystem nature of mTBI symptomatology nor the complex cognitive and sensorimotor demands of duty. Traditional standardized rehabilitation assessments are also inadequate and have not been validated on this population. Most functional assessments used in physical and occupational therapy were designed for patients with stroke and moderate to severe TBI, have ceiling effects, and who lack sensitivity to mTBI-related vulnerabilities.¹⁶ Finally, existing return-to-duty assessment protocols (as described above) have not been empirically evaluated or validated.

To improve return-to-duty decisions for SMs with mTBI, medical personnel require sensitive, objective, and duty-relevant data. Military leaders have called for standardization of return-to-duty decision making in theater and stateside settings through use of objective, functional assessment that challenges multisystem mTBI symptoms.⁶ Widely used but poorly specified, the term "functional assessment" generally refers to the systematic attempt to objectively measure the level at which a person is functioning in various aspects of life (e.g., health, roles, activity).¹⁷ At present, no such assessment exists for mTBI, much less for SMs with mTBI, and innovative alternatives are needed.

With funding from the U.S. Army Medical Research Materiel Command (USAMRMC), a military-civilian rehabilitation research team has begun to address the need for an mTBI-specific functional assessment to provide guidance regarding duty readiness. This article summarizes a 1-year project, in which the team developed a preliminary protocol for the Assessment of Military Multitasking Performance (AMMP), a functional assessment designed to challenge the vulnerabilities commonly seen after combat-related mTBI and help inform return-to-duty decision making. The project had two central goals: (1) to specify the assessment concept and (2) to develop a protocol comprising military-related test-tasks that are sensitive to multisystem mTBI symptoms and produce objective scores.

METHODS

The team used an iterative development process to ensure strong clinical feasibility, psychometric properties, and face validity for stakeholders (leaders and policy makers with interest and influence in matters related to return to duty) and end users (clinicians who currently make or contribute to return-to-duty decisions). The first two steps involved analysis of existing literature and collection and analysis of stakeholder, end user, and researcher input.

Analysis of Existing Literature

The team conducted an extensive literature review to identify existing assessment methods for detecting impairments following mTBI that involve combined motor and cognitive skills with emphasis on dual-task and performance-based assessment methods.

Dual-Task Assessment Methods

Dual-task assessment methods require that an individual perform a primary motor task (such as walking) while simultaneously performing a secondary cognitive task (such as remembering or mental arithmetic).^{18,19} Reduced performance of one task when performed with the secondary task reflects the "cost" of performing tasks simultaneously. This is often measured as the added number of errors or added time required for the two tasks versus the primary motor task. Deficiency in dual-task performance is associated with safety

problems, which may not be evident if motor or cognitive tasks are assessed singly and not in combination.²⁰⁻²³

Dual-task costs are significantly greater in people with concussion than those observed in age-matched control subjects.²⁴ Dual-task costs have been documented in walking speed, variability, and stability; the ability to perceive and avoid obstacles is also impaired.^{20,24-27} In laboratory studies following sports concussion, cognitive dual-task costs manifest as slower reaction and response times and increased task error.^{25,27,28} Dual-task costs are particularly evident when combining visuospatial tasks with balance tasks.²⁹⁻³² Dual-task deficiencies following mTBI are not confined to postural control tasks. Dual-task deficits have also been observed following mTBI during concurrent upper extremity and math tasks.³³ After mTBI, some people have problems allocating attention to accomplish two tasks simultaneously³³ (evidence of executive dysfunction³⁴), which may explain decrements in dual-task performance.

The literature suggests that existing dual-task measures are problematic in terms of practicality and military relevance. Most studies of dual-task methods employ laboratory methods with precise measurement equipment during basic postural control functions, such as standing or walking. The sophisticated instrumentation needed to discern subtle variations in movement is not readily available in the typical clinical environment, much less in the deployed setting. Furthermore, the motor demands of SM's activities (e.g., running while carrying a load over uneven terrain in a complex environment) are vastly different from simple standing or walking tasks. However, although existing measures have limitations, the literature suggests that dual-task methods may be important in the development of a functional assessment for return-to-duty decision making after mTBI.

Performance-Based Assessment Methods: Multitasking

Performance-based assessment requires the patient to perform a task (or tasks) that simulate an everyday activity, "...under the observation of the examiner, who utilizes behaviorally-based measures to quantify different aspects of functional capacity."³⁵ Many disciplines and fields (e.g., occupational therapy, educational psychology, neuropsychology) use this assessment approach to characterize activity performance under standardized, directed conditions.³⁶ Performance-based assessments vary widely in their structure and complexity, ranging from simple activities of daily living³⁷ to assessments involving complex multitasking.³⁸⁻⁴⁰ Performance-based multitask assessments approximate how the person will perform a complex activity that requires many cognitive and motor processes necessary in a real-world environment, often described as an "ecologically-valid" approach.⁴¹ Multitasking assessments include several common features: many tasks are required; tasks are dovetailed; only 1 task is performed at a time; interruptions occur unexpectedly; and one must remember to do a task at some point in the future during the assessment.⁴² There is

growing evidence that performance-based assessments that involve multitasking discriminate between healthy controls and individuals with executive dysfunction.³⁸⁻⁴⁰

Several performance-based multitask assessments focus on executive dysfunction and frontal lobe damage associated with stroke and TBI.^{38,39,43} Some assessments use tasks that are overly simple and lack face validity in a military context. For example, the Naturalistic Action Test was developed for adults with stroke and TBI and examines performance of learned sequences of movement involved in making toast and coffee and wrapping a gift.⁴³ Others are more complex but still lack military face validity. The Complex Task Performance Assessment⁴⁰ requires patients to complete a library inventory control sheet while periodically answering the telephone and taking messages and managing prospective memory tasks. The Multiple Errands Test is the most studied of the performance-based multitask assessments.^{38,39,44} It requires the patient to organize and perform a series of unstructured errands in either a shopping mall or hospital while adhering to task rules and remembering prospective memory tasks. With all of these tests, the evaluator observes performance, characterizes errors of action (e.g., omission, rule breaks, sequencing, accuracy), and records performance time. Although this test concept holds promise for sensitivity to mTBI symptoms, no existing performance-based multitask assessments could be directly adopted for inclusion in the AMMP because they are either irrelevant to typical military duty, lengthy, or lack clinical feasibility.

Stakeholder, End User, and Researcher Input

Interviews with stakeholders, end users, and researchers were conducted early in the project to clarify military issues and rehabilitation practices in return-to-duty decision making, including current assessment methods and mTBI symptoms driving duty-readiness decisions. Referral sampling was used to identify 53 potential interviewees from military medical leaders, line commanders, occupational and physical therapists who provide services to SMs with mTBI, physicians who make return-to-duty decisions as part of medical boards, and test development experts in dual-task and multitasking paradigms (Table I). Thirty-five of these individuals agreed to participate in telephone interviews, with 33 ultimately giving written informed consent and participating in a private semistructured interview (Allina Institutional Review Board Number 2685-1X; USAMRMC Human Research Protection Office Log Number A-15671).

Seven 30 to 45 minute interview scripts/questions were developed and tailored to capture pertinent input from the varied participant groups. Interviewers followed the script and posed follow-up questions as needed to gain more depth or specific information. Interviews were audio-recorded, transcribed by a commercial provider, and checked for errors in transcription or interpretation by the principal investigator

TABLE I. Interviewees

Background Category	Number Invited	Number Consented	Number Interviewed
Return-to-Duty Expert ^{a,b}	1	1	1
Occupational/Physical Therapist ^c	12	9	9
Dual Task Expert ^b	8	4	4
Functional Assessment Expert ^b	6	3	3
Line Command ^c	4	3	3
Medical Board ^c	4	3	3
Medical Stakeholders/ Medical Leadership ^a	14	8	7
Military Medical ^{a,c}	2	2	2
Neuropsychologist ^{b,c}	2	2	1

^aStakeholder. ^bResearcher. ^cEnd user.

before analysis. Transcripts were assigned identification codes to maintain confidentiality and to blind reviewers.

Transcripts went through multiple phases of analysis. During the first phase, two members of research team read each transcript and identified central categories and themes, which were subsequently discussed by the entire team. In the next phase, two members of the research team reviewed and extracted contents of each interview transcript and entered interview data into the analysis template based on five key areas of input (Table II). Next, aggregate analyses were performed in which frequency of codes within categories were assigned, reviewed, and consolidated based on overarching themes. The results were reviewed, revised, and ultimately approved by the entire research team as accurately reflecting the process and findings of the stakeholder interviews. Interview findings relative to the five key areas of input are summarized in Table II.

Throughout the project, consultants with expertise in dual-task and multitask assessment informed the development and refinement of the test-tasks that ultimately comprised the AMMP assessment protocol. This included periodic teleconference calls with consultants and a daylong consultation with one expert who has studied both dual and multitask assessment approaches in TBI.

RESULTS

Analysis of stakeholders' requirements and needs, findings from the literature review, and expert consultation informed the specification of AMMP concept and development of multiple prototype test-tasks, which ultimately comprised the AMMP Version 1.0.

Concept Specification

The above processes supported a functional assessment concept with the following attributes: employs dual-task and multitasking assessment methods; sensitive to mTBI-related vulnerabilities; comprises test-tasks based on military scenarios that simultaneously challenge cognitive and sensorimotor systems in ways that approximate the demands of military occupational tasks. Recognizing that clinical test-tasks and environments can never simulate real-world military demands, the team adopted a verisimilitude approach to ecological validity.³⁸ In this approach, although the characteristics of the test protocol may differ from the real-world tasks, the stimuli and cognitive-sensorimotor demands of the test protocol resemble that of the real-world task or environment.^{45,46}

AMMP Version 1.0

An array of test-tasks were developed to assess SM's proficiency in performing complex, military-relevant tasks that collectively challenge cognitive functions (attention, memory, executive function, visual and auditory information processing, and reaction time), sensory functions (visual tracking and eye gaze stability, and vestibular function), and motor functions (bending/lifting, balance, exertion, and motor speed). Table III lists the five complex/multitask test-task scenarios and three dual tasks that comprise the AMMP Version 1.0.

As indicated earlier, none of the existing dual-task or multitasking assessments was suitable for direct inclusion in the AMMP. However, the team worked with experts in dual-task and multitask assessment to use existing measures with established sensitivity to mTBI-related vulnerabilities

TABLE II. Key Findings From Stakeholder Inquiry

Key Areas of Input	Interview Findings and Impressions
Assessment for Duty Readiness After mTBI	Clinicians currently use a variety of assessments and methods to inform return-to-duty decision making. Some interviewees reported that no formal assessments are performed as part of return-to-duty decision making and that some of the methods used are not informed by research evidence. Decision makers consider a number of factors when determining duty readiness after mTBI, including the SM's ability to dual task/multitask, his/her social skills, and the SM's own appraisal of his/her readiness.
Test Construction	AMMP should challenge performance vulnerabilities associated with mTBI symptoms that potentially interfere with duty readiness. The most frequently cited vulnerabilities that interviewees suggested should be challenged by the AMMP included balance/vestibular function and cognition such as attention in the presence of distracters.
Requirements for Adoption	To be successfully adopted by the military, the AMMP must have demonstrated reliability and validity and meet practical requirements pertaining to administration time (e.g., maximum administration time ranging from 30 minutes to 2 hours; ease of setup and storage).
Validation Planning	In future phases of test development, researchers are advised to utilize existing expertise, facilities, and already validated tests and tasks.

TABLE III. Multitasks and Dual Tasks Comprising AMMP Version 1.0

Task/Test ^a	mTBI Symptom Domains										
	Cognitive			Reaction Time	Sensory			Physical			Manual Speed
	Executive Function	Memory	Attention		Eye Gaze Tracking	Scanning	Vestibular	Balance	Exertion	Bend-Lift	
MULTITASKS											
“Shipping” requires establishing a work plan to efficiently pack cartons by weight capacity	●	○									○
“Duty roster” requires scheduling staff duty while monitoring a recording of a staff meeting and noting what is relevant to specific unit	●	○	●			○					
“Run-Roll-Aim” requires running, rolling, obstacle avoidance, and aiming at visual targets			○		●		●	●	○		
“A-bag packing” task requires alternating between packing an A-bag from a list of items and finding visual targets on a large wall-mounted map		●	○			●					○
“9-line/SALTE Report” requires collecting visual and auditory information during physical exertion	○	○	●			●	○	○	●		
DUAL TASKS											
Illinois agility test word list dual task		●	○					●	○		
Step initiation-Stroop dual task	●			●				○			
Load magazine/radio chatter dual task	○		●								●

^amTBI-related task challenges: primary, ●; secondary, ○.

as prototypes to develop an array of novel dual-task and multitasking test-tasks based on military scenarios. For example, the "Duty Roster" multitasking test-task uses the structure of the Complex Task Performance Assessment⁴⁰ but requires completion of a multiple week military duty roster while listening to a military briefing for key information as directed by the examiner. Similarly, the "Load a Magazine" test-task (quickly loading a magazine while listening for specific content within radio chatter) is modeled after the upper extremity dual task discussed earlier.³³ In a similar fashion, the team modeled AMMP test-task scoring metrics after existing dual-task measures (dual-task cost) and performance-based multitasking assessments (task completion time and accuracy and frequency and categories of observed errors related to sequencing, rule breaks, subtask omissions etc.). In designing test-tasks, the research team also studied skills considered to be essential to all military personnel, as described in the *Soldier's Manual of Common Tasks*.⁴⁷ Additional complex test-tasks were created that specifically challenge the ability to integrate physical exertion with cognitive and sensorimotor function. For example, the "Run-Roll-Aim" task requires rapid head position changes in a 3-to 5-second rush and combat rolls, thus requiring at least minimum stamina and challenging for individuals with vestibular impairment. The "SALTE" task requires that SM view and remember a simulated video scenario while performing an exercise step test, simulating the visual oscillations that would occur on foot-patrol with exertion. At the end of the test, the SM must provide an accurate "SALTE" report (size, activity, location, time, and equipment). Each test-task was subject to multiple revisions based on team discussion and problem solving, expert consultation, stakeholder input, and the results of preliminary testing.

Near the end of the project, a Summit Meeting was convened at the National Intrepid Center of Excellence in Psychological Health and TBI (Bethesda, MD) involving 15 participants (stakeholders, end users, and subject matter experts) and the research team. Summit participants reviewed the findings of the process, endorsed the AMMP concept, gave input regarding the functionality and military relevance of preliminary test-tasks developed by the research team, and supported the AMMP's potential utility in informing return-to-duty decision making in deployed and stateside settings.

After formal completion of the 1-year project, the research team conducted a weeklong concept validation exercise at the U.S. Army Research Institute of Environmental Medicine (Natick, MA) in which ten healthy soldiers performed the AMMP Version 1.0 test-tasks (total administration time ranging from 2.0–2.5 hours). Performance observation and formal feedback from participants in the validation exercise provided preliminary evidence to support face validity and objective scoring of test-tasks. This input also informed protocol modifications, refinement of scoring procedures, and preliminary test sequence optimization with the ultimate goal of reducing administration time closer to the 30-to 60-minute

time frame preferred by end users. The Institutional Review Board overseeing the work stipulated that data from the validation exercise be used exclusively for refinement of assessment methods; therefore, data from the exercise is not included in this report.

DISCUSSION

In a 1-year project, an interdisciplinary research team launched preliminary work to respond to the Army's need for an objective, relevant, functional assessment to help standardize and inform return-to-duty decision making after mTBI. The team used stakeholder and expert input and existing research literature to develop the resulting AMMP protocol. This approach is consistent with methods designed to drive dissemination of new information by trying to understand the needs and constraints of the practitioners who may benefit from the protocol in future clinical practice. Throughout this process, investigators were particularly sensitive to factors deemed critical to long-range adoption including potential test-task reliability and validity, clinical utility, face validity, and the capacity to challenge mission-critical mTBI vulnerabilities.

Assessment development in any area of medicine or rehabilitation is a lengthy and complex process, and developing a functional assessment to inform return to duty after mTBI faces some specific challenges. First, controversy remains regarding the precise symptoms of mTBI and their duration.⁴⁸ In addition, the civilian literature offers limited existing options for functional assessment after mTBI: most dual-task measures that are sensitive to high-level postural control disturbances require expensive instrumentation and performance-based multitasking assessment is in its relative infancy. Experts in sports-concussion are also trying to identify new tools and methods to specify symptom resolution after concussion.¹¹ Finally, the research team appreciated that SMs (with or without mTBI) are unlike typical "healthy controls" or rehabilitation clients. SMs' baseline levels of fitness and agility and the demands of their daily activities make traditional rehabilitation evaluation measures irrelevant. These realities and the critical nature of return-to-duty decisions necessitated the innovation-oriented approach to concept specification and protocol development.

There were limitations to the AMMP development process. Experts, consultants, and Summit participants may have been biased in their recommendations or offered opinions, not widely shared among most military leaders, practitioners, or researchers. Although repeated analyses were performed of stakeholder interview data to optimize objectivity of findings and impressions, researchers may have been vulnerable to hearing and reading information that conformed to their own opinions and preferences. Furthermore, protocols for existing standardized military tasks (such as those described in the *Soldier's Manual of Common Tasks*⁴⁷) did not easily lend themselves to modification with dual or multitask overlays. Therefore, researchers developed military test-task scenarios modeled after existing measures and metrics.

A follow-on 2-year study was recently funded. The goals of this effort are to establish reliability and preliminary validity and to further refine the test battery based on logistic requirements (e.g., administration time, cost, storage space required) and psychometric properties of test-tasks. This study will also examine whether or not the test differentiates between SM with mTBI and those who are healthy, and the extent to which SM task performance correlates with performance on known neuropsychological, sensorimotor, and physical measures. Future validation will determine whether or not AMMP test-tasks present equal challenge to SM with mTBI from various military occupational specialties as well as addressing internal validity threats related to the test, testers, and the population being examined. The potential practice effects of test components are an important factor that will be considered in the funded study. Administration of dual tasks will include preliminary practice repetitions to account for learning effects. The need for parallel forms of the multitask assessments will be necessary if the AMMP is to be used for repeated tests, as these scenarios represent a novel "problem to be solved" that will likely benefit from an effort to derive a solution. Practice effects of novel dual-task scenarios will also be quantified so that change in performance of two test administrations can be interpreted based on indices of responsiveness.

The extent to which the AMMP may differentiate individuals with mTBI from those who are healthy may be affected by examiner bias, if history of injury is known. Given the complexity of issues that could cause difficulty with military duty, there is the potential for other factors to contribute to performance problems (e.g., musculoskeletal pain, ongoing stress reactions, social factors, incentives or disincentives to return to duty). Therefore, the test administrator will be blinded to comorbidities and health history when administering the tasks. Data on these potential covariates will be collected for analysis in the funded project.

The AMMP is not intended as a diagnostic test of mTBI, rather a method to reflect areas of performance that could cause problems with return to duty. Future study will specify typical performance standards on the AMMP that will allow decrements to be identified regardless of reasons and provide military decision makers with additional information upon which to base important return-to-duty judgments.

CONCLUSIONS

mTBI remains a significant threat to Warfighters, although its effects can be challenging to detect within deployed and clinical environments. Military medical and rehabilitation practitioners consider many factors in making return-to-duty decisions but at present, lack valid and reliable performance data regarding how an SM with mTBI performs tasks that place simultaneous demands on cognitive and sensorimotor systems. Functional assessment protocols such as the AMMP may provide additional information to assure the soundness and standardization of return-to-duty decision making so that

after mTBI, SMs are able to function safely and advance mission objectives.

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Returning Service Members to Duty Following Mild Traumatic Brain Injury: Exploring the Use of Dual-Task and Multitask Assessment Methods

Matthew R. Scherer, Margaret M. Weightman, Mary V. Radomski, Leslie F. Davidson, Karen L. McCulloch

Within the last decade, more than 220,000 service members have sustained traumatic brain injury (TBI) in support of military operations in Iraq and Afghanistan. Mild TBI may result in subtle cognitive and sensorimotor deficits that adversely affect warfighter performance, creating significant challenges for service members, commanders, and clinicians. In recent conflicts, physical therapists and occupational therapists have played an important role in evaluating service member readiness to return to duty (RTD), incorporating research and best practices from the sports concussion literature. Because premorbid (baseline) performance metrics are not typically available for deployed service members as for athletes, clinicians commonly determine duty readiness based upon the absence of postconcussive symptoms and return to “normal” performance on clinical assessments not yet validated in the military population. Although practices described in the sports concussion literature guide “return-to-play” determinations, resolution of symptoms or improvement of isolated impairments may be inadequate to predict readiness in a military operational environment. Existing clinical metrics informing RTD decision making are limited because they fail to emphasize functional, warrior task demands and they lack versatility to assess the effects of comorbid deficits. Recently, a number of complex task-oriented RTD approaches have emerged from Department of Defense laboratory and clinical settings to address this gap. Immersive virtual reality environments, field-based scenario-driven assessment programs, and militarized dual-task and multitask-based approaches have all been proposed for the evaluation of sensorimotor and cognitive function following TBI. There remains a need for clinically feasible assessment methods that can be used to verify functional performance and operational competence in a variety of practice settings. Complex and ecologically valid assessment techniques incorporating dual-task and multitask methods may prove useful in validating return-to-activity requirements in civilian and military populations.

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Over the last decade, in excess of 220,000 military service members have sustained traumatic brain injury (TBI) (Box 1), resulting in significant morbidity and a commensurate degradation of military operational readiness.^{1,2} Current criteria to assess readiness to return to duty (RTD) in an operational environment following mild TBI (mTBI) are based primarily on clinical best practices and evidence from the sports concussion literature.³⁻⁷ Although widely used, it is not clear that existing return-to-play (RTP) guidelines developed for the management of sports-related blunt head trauma are sufficient to detect subtle and potentially duty-limiting effects of deployment-related mTBI.⁸ The purposes of this article are to provide perspective on the current state of mTBI assessment in the military practice environment and to introduce alternatives given emerging requirements for more rigorous, feasible, and ecologically valid methods to guide RTD decision making. We propose a rationale for shifting the RTD readiness assessment model from an impairment-based approach to a more functionally oriented and standards-based paradigm. Finally, we highlight relevant findings from the dual-task and multitask literature that support this proposed approach to RTD assessment.

Box 1. Traumatic Brain Injury (Definition)

The Department of Defense (DoD) defines traumatic brain injury as head injury (via blunt trauma or barotrauma, or both) resulting in even momentary alteration of consciousness, loss of consciousness, or posttraumatic amnesia. Mild traumatic brain injury is further characterized as meeting one or more of the following criteria: loss of consciousness for 0 to 30 minutes, alteration of consciousness or mental state for a moment or up to 24 hours, and posttraumatic amnesia for up to 1 day.

RTD Following TBI in the Deployed Environment: What Is the Scope of the Problem?

According to Department of Defense (DoD) estimates, approximately 165,000 (75%) of the 220,000 TBIs sustained by US service members over the last decade have been classified as mild.^{1,9} Although these numbers are significant, recent epidemiological studies suggest the prevalence of head injury in returning service members may be even greater, with an estimated 11.2% to 22.8% of returning personnel screening positive for mTBI during their deployment.¹⁰⁻¹⁴ Blast or explosion as a mechanism of injury is known to account for as much as 78% to 80% of in-theater-related TBI.^{9,10} Although evidence suggests recovery from blunt head trauma occurs days to weeks after injury, recovery from blast-related mTBI is less understood.⁵ Relative to blunt head trauma, injuries from blast exposure generally result in a more complicated clinical presentation characterized by greater frequency of headache, facial injury, visual and hearing impairment, elevated levels of vestibular morbidity, and more severe posttraumatic stress syndrome symptoms.¹⁵⁻¹⁸ Given the morbidity and persistent sequelae associated with mTBI sustained in-theater, there is legitimate concern among military medical providers and commanders that such complexity may result in a more challenging RTD process, with direct implications for operational readiness of the fighting force. Furthermore, with approximately 80% of military TBIs occurring in non-combat environments, management of TBI-related sequelae and their potential impact on readiness represents a persistent and challenging military health issue for the foreseeable future.¹

RTD Decision Making: A Page From the "RTP" Book? Challenges to RTD Decision Making in the Military Practice Environment

In recent years, the "tactical athlete" analogy has increasingly been used to describe the highly functioning personnel within the ranks of the military, law enforcement, and fire-fighting professions. The description of the modern warrior-athlete fits within a broader "sports medicine on the battlefield" concept that emphasizes early, far-forward management of injured military service members with the intention to return them quickly to the battlefield. This model has been readily adopted for the management of musculoskeletal injury, although its utility for managing RTD determinations among service members with concussion has yet to be validated.

In the deployed environment, DoD policy dictates that physical therapists and occupational therapists administer functional RTD assessments of concussed service members.³ Military physical therapists and occupational therapists are well suited to perform these assessments, given their existing doctrinal mission within the force. Occupational therapists are typically key providers in concussion care centers in the deployed setting and are highly familiar with combat stress issues. Physical therapists are assigned directly to Brigade Combat Teams and have the clinical training to perform neurologic assessment and rehabilitation. Physical therapists provide a broad spectrum of services to their units ranging from health promotion and performance optimization to direct-access patient care.^{19,20}

Current in-theater policy guidelines require mandatory neurological and functional evaluations for personnel exposed to a specified number of

blast-related or blunt trauma-related events.³ Additionally, official guidance establishes progressively longer mandatory rest periods for concussed service members following each successive incident.³ Physical therapists and occupational therapists facilitate recovery and decrease risk of cumulative injury by focusing on early rest and graded return to activity.^{21,22}

The sports concussion literature has provided a valuable starting point from which to evaluate RTD assessment procedures following mTBI in both deployed and continental United States (CONUS)-based clinical practice environments. However, after more than 5 years of military TBI research, legitimate questions remain regarding the sensitivity of symptom- and impairment-based testing paradigms for informing return-to-activity decisions in concussed service members.²³ Within the military context, current RTD decisions are made by focusing on symptom resolution, neurocognitive testing, and clinical balance assessments as primary indicators of duty readiness.

Symptomology

Following a concussive event, a service member may experience a variable range of sensorimotor, cognitive, and physical sequelae related to primary or secondary injuries affecting body structure or function. These symptoms may include headaches, dizziness, imbalance, tinnitus, hearing loss, impaired cognitive processing, dysexecutive syndrome, musculoskeletal pain, or comorbid stress symptoms.^{24,25} Military medical treatment facilities, especially those in a deployed setting, are currently challenged to objectively assess the spectrum of vulnerabilities associated with mTBI. Department of Defense evidence-based clinical practice guidelines neither support nor discount reliance on patient self-

report of symptoms for the management of mTBI.²⁶

Until recently, with the widespread adoption of the Zurich guidelines for concussion management, symptom resolution (in the absence of more objective findings) may have driven premature RTD decisions.²¹ Such decision making can be particularly challenging in deployed environments, where sensitive and objective measures to justify “sidelining” the service member often are unavailable. The risk of premature RTD is further elevated by the tendency of personnel to downplay or “underreport” symptoms to hasten their return to their unit.²⁷ If not checked with more stringent assessment measures, the pervasive willingness within military culture to push through discomfort and “accomplish the mission” following concussion could lead to an elevated risk of postconcussive syndrome, increased likelihood of subsequent exposure, or greater risk to self and members of the unit resulting from the injured service member’s diminished situational awareness.²⁷

Recent in-theater efforts to increase the sensitivity of symptom self-report under more challenging and realistic conditions have included the introduction of a 2-minute RTD exertion test. Similar to the concept of exertion testing in the sports concussion community, service members with mTBI who are symptom-free at rest or under light exertion conditions are pushed to perform under more strenuous (typically 65%–85% of age-predicted maximum heart rate) conditions to probe for postconcussive symptoms.^{28,29} Functional RTD tasks range in difficulty from donning and doffing of body armor and helmet to road marching (with a load) or sprinting short distances. Variations of exertional testing also have included the use of push-ups, treadmill running,

or step aerobics.⁸ Although therapists are directed to perform functional testing, there is no clear standard for testing across practice settings or branches of service.

Although not a “gold standard” diagnostic metric, there is an implicit responsibility for peers and leaders to observe and confirm a service member’s readiness to resume duty when he or she returns to the unit.³ Subtle behavioral abnormalities suggesting persistent mTBI-related impairments often are first identified not by the service member or even by the provider, but by fellow warriors (in a deployed setting) or family members while at home.¹³ Persistent postconcussive sequelae may vary widely and include difficulty sleeping, irritability, trouble with peer or family relationships, difficulty navigating uneven or urban terrain under dimly lit conditions, or a diminished capacity to concurrently accomplish multiple activities (ie, multitask) relative to one’s premorbid capabilities.³⁰ Because unit leadership may be among the first to identify behavioral health systems, unit leadership can play an important role in initiating appropriate management and support actions if such symptoms, behaviors, or deficient performance areas are identified.

Clinical Impairment Testing

Neurocognitive assessment batteries used by military providers and researchers for mTBI screening, management, and monitoring include, but are not limited to, the Automated Neuropsychological Assessment Metrics (ANAM) and the Immediate Post Concussion Assessment and Cognitive Testing (ImPACT).^{31,32} Neurocognitive testing has been recommended for the assessment of suspected concussion in both civilian and military practice settings. However, it is difficult to interpret findings, as there are no normative data for service members

in a deployed setting. Furthermore, these tests lack face validity for service members and commanders anxious to keep “boots on the ground” in an operational setting.^{27,33,34}

Balance testing also is commonly incorporated into postconcussive evaluations, either independently or in conjunction with a broader multimodal assessment. Although research indicates that a person’s cognitive performance as measured by automated neurocognitive testing typically returns to normal within 1 week of a concussive incident, deficits in balance as measured by the Balance Error Scoring System (BESS) or force platform systems reveal impairments that outlast discernible cognitive symptoms.^{4,35–37} Recent findings confirm significant recovery time disparities among the most commonly considered RTP indicators, including symptom self-report, balance assessment, and neurocognitive testing, among concussed athletes.³⁸ Lack of congruency across symptom, balance, and neurocognitive domains casts reasonable doubt on the validity of single-domain assessment measures for the identification of duty limiting impairments in people with subtle (but significant) deficits. Complex warfighting tasks represent a confluence of multiple domains demanding simultaneous functioning from all. If a provider bases RTD decisions solely upon the absence of isolated impairments in a single domain (without a relevant multimodal functional assessment), the risk of premature RTD increases. To date, assessments of cognition and balance have not been found to be predictive of postconcussive symptom development or readiness to return to activity.³⁹ Neither of these relationships has been systematically investigated in a military population.

Limitations of Current Clinical Tests for Military Populations

Existing clinical tests being used to assess injured service members are hampered by psychometric and practical issues. Clinical measures used by deployed physical therapists and occupational therapists lack sensitivity to high-level functional deficits revealing ceiling effects when used to assess a highly conditioned warrior population.⁴⁰ These tests lack face validity among injured service members and their leaders because it is unclear how substandard performance on an isolated body structure-based or function-based task (eg, tandem standing) relates to performance in one’s role as a combatant. The use of existing clinical measures is further complicated by the lack of normative values in the typical age and activity range of the service member. Although there are many measures that have been demonstrated valid and reliable to predict falls or other adverse outcomes in aging or clinical populations with more severe neurologic pathology, such evidence is lacking in service members who sustain mTBI. Service members in military operations commonly experience significant physical and mental fatigue, elevated stress levels, inadequate or disrupted sleep, and variability in hydration and nutrition.^{41–44} As most research on natural recovery following sports concussion is based on care provided under optimal clinical conditions, it is unclear how exposure to psychologically and physiologically stressful conditions before, during, or even after clearance to RTD might affect outcomes.

A Standards-Based Approach to RTD Decision Making From Structure and Function to Activities and Participation

The previous section highlighted a number of symptoms and impairments believed to degrade duty readiness. However, in addition to symptoms of physical discomfort, sensory instability, or disorientation, acutely concussed personnel may experience activity- or participation-level performance deficits in previously highly practiced and well-trained military occupational competencies.^{27,45,46} Postconcussive activity-level deficits in service members, for example, may include impaired marksmanship (stemming from gaze instability, visual, or central processing deficits), degraded situational awareness (related to diminished visual, auditory, or central cognitive processing capabilities), or difficulty engaging in radio communications (due to central auditory or cognitive processing impairments). Such deficits likely reflect diffuse involvement across multiple domains (eg, sensorimotor, cognitive, musculoskeletal) and, although subtle in some cases, can clearly have duty-limiting or even career-limiting implications if improperly managed. Deficits associated with concussion also may result in participation restrictions (Box 2). Duty limiting barriers to participation may range from distraction or prolonged reaction times during patrolling by an infantryman, or degraded telecommunication performance by a radio operator, to unsafe or poorly executed vehicle handling during convoy operations by a truck driver. Impaired service member job performance has significant implications for safety and operational effectiveness for the individual, unit, and mission.

Box 2. International Classification of Functioning, Disability and Health (ICF) Model of Functioning and Disability (Definitions)

Body functions are physiological functions of body systems (including psychological functions).

Body structures are anatomical parts of the body such as organs, limbs, and their components.

Impairments are problems in body function or structure such as a significant deviation or loss.

Activity: qualified as an individual capacity (ie, the ability to execute a task or an action) or performance (the ability of the individual to perform an activity in his or her current environment).

Participation: Involvement in a life situation.

Participation restrictions are problems an individual may experience in involvement in life situations.

The *International Classification of Functioning, Disability and Health* (ICF) model provides a framework to illustrate the complex interplay of factors, including the health condition of concussion, affected body structure or body function systems, task performance deficits, and personal or environmental factors that collectively contribute to limitations in duty readiness or operational competence (Figure).⁴⁶

Theoretical and Practical Basis for a "Standards-Based" RTD Model

The process of defining a service member's duty readiness is complex. Competence as a warfighter demands not only technical prowess in military skills, it also necessitates resilience, self-efficacy, the capacity for complex thought, and other personal factors highlighted in the Figure, which are both abstract and difficult to measure using conventional clinical or impairment-based means. Within the field of development economics, Sen⁴⁷ has described individual capabilities as vectors (in the mathematical sense), which may be summed together to obtain an abstract representation of one's total level of functioning. From a theoret-

ical perspective, we might draw on this approach and conceive of readiness as the vector-sum of relevant military competencies and other nonparametric characteristics (such as the capacity for complex thinking, resilience, or even self-efficacy) deemed critical for mission success. This approach acknowledges and normalizes the heterogeneous nature of inputs into the readiness equation and accounts for individual differences in outcomes based on an individual's premorbid capability set and coping strategies. Conceptually, this approach mirrors the complex contributions to functioning in the framework posed by the ICF model.

Existing military performance standards require demonstrated competence in warfighting capabilities (ICF: activity/participation level), based on well-established tasks, conditions, and standards.⁴⁸ Currently, clinical decisions guiding RTD following concussion are objectively informed primarily at the level of body structure and function.²⁷ One might argue that given the variability inherent in human functioning and performance, any attempt to quantify a participation level construct such as duty readiness should be informed by activity- or participation-level performance metrics. It is likely that any advance in readiness assessment methods not recognized as ecologically valid by the warfighter community will fall short in key domains of realism, generalizability, and complexity necessary to determine safe and appropriate return of injured service members to duty.

Foundational competencies or standards of soldiering are described in terms of warrior tasks and battle drills.⁴⁸ Formally defined, *warrior tasks* are a collection of individual soldier skills deemed critical to soldier survival, including activity-level competencies such as proficiency

with weapons handling, communications skills, or negotiating obstacles. Duty readiness in the operational environment also requires proficiency with integrated, multiperson, unit-level activities known as *battle drills*. These participation-level competencies are complex "tasks performed as a part of a unit in order to react and survive in common combat situations" and include a range of activities from dismounted patrolling to casualty evacuation.⁴⁸ According to existing military operational competence standards, individual and collective service member proficiency in these types of complex military tasks are essential for an organization to be deemed mission ready.

In order to objectively measure service member performance in a way that is ecologically valid, an assessment must simulate the vocational demands of military tasks, demonstrate complexity adequate to account for fluid conditions in an operational environment, and challenge known mTBI-related vulnerabilities. Although the idea of assessing service member performance on unmodified warrior tasks to guide RTD decisions might be attractive from the standpoint of simplicity, such an approach can be problematic from a clinical perspective. Without a consistent methodological approach, clinicians may find interpretation of performance challenging. For example, if the tested service member is experienced, he or she may be able to rely on rote motor memory even in the presence of residual deficits if the tested task is not assessed with elements of complexity or unpredictability associated with a real-world scenario.

Application of the ICF Model for RTD Determination

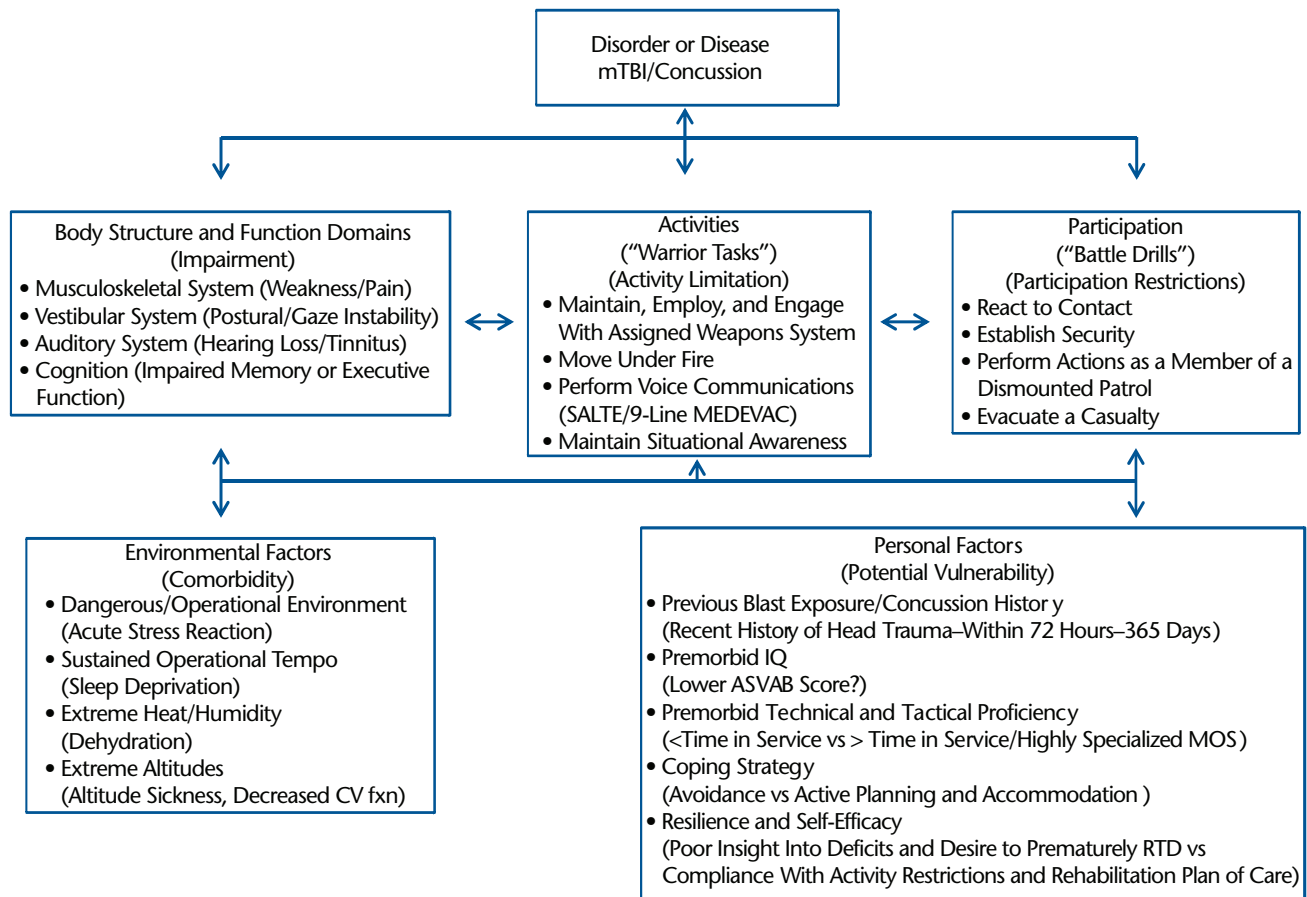


Figure.

International Classification of Functioning, Disability and Health (ICF) model for service member capabilities and vulnerabilities. This model highlights service member capabilities and limitations at every level of consideration. Body structure and function deficits include known vulnerabilities affecting functioning at the systems level and behavior. Activity and participation blocks summarize relevant warfighting task skills of varying complexity among duty-ready service members who are healthy. Finally, environmental and personal factors influencing service member resilience propose theorized limits on service member performance. RTD=return to duty, mTBI=mild traumatic brain injury, SALTE=Size Activity Location Time Equipment Intelligence Report, 9-Line MEDEVAC=Standardized Military Medical Evacuation Request, ASVAB=Armed Services Vocational Aptitude Battery, MOS=Military Occupational Specialty, CV fxn=cardiovascular function.

Complex Task Assessment Following mTBI in the Military Treatment Environment

Although not yet widely available throughout the DoD, preliminary efforts in select military treatment facilities and laboratories to assess mTBI-related deficits have focused on developing realistic duty scenarios to challenge service members across the range of functioning (ie, body function to activity level

demands). These approaches include highly sophisticated, immersive virtual reality (VR)-based assessments; observational, scenario-based programs; and more clinically oriented testing that draws on components of each.^{40,49,50}

Immersive VR systems such as the Computer Assisted Rehabilitation Environment (CAREN) provide highly sensitive, instrumented means of assessing physical, sensorimotor,

and cognitive performance during ambulation and other functional movements in a laboratory-based environment.^{49,51} Use of instrumented VR systems are advantageous because they allow an examiner to assess multiple performance domains simultaneously or to probe specific deficits by manipulating relevant sensory stimuli. As a clinical tool, the CAREN has been used extensively within larger DoD medical centers to assess and treat duty-

limiting postconcussive deficits in service members using highly realistic operational scenarios and complex task conditions.^{49,51} Although this type of RTD approach has great versatility and numerous applications for assessing and managing service members with concussion, obvious barriers to widespread use include cost; the requirement for specialized technical support to program, run, and maintain the system; and the relative immaturity of evidence to support generalizability of “readiness” in a virtual environment to “fitness for duty” in an operational environment.

In contradistinction to the laboratory-based VR approach, recent efforts by rehabilitation providers at military installations such as Fort Campbell, Kentucky, and Fort Bragg, North Carolina, have made significant progress in developing RTD testing modules that integrate traditional military training techniques with observational methods from a multidisciplinary team.⁵⁰ These scenario-based RTD programs assess a broad range of competencies ranging from individual warrior tasks such as marksmanship, vehicle rollover extrication, and land navigation to more challenging, small group-oriented battle drills such as VR convoy operations or simulated combat lifesaver operations. Specially designed assessment modules challenge service member performance under highly realistic and progressively more difficult operational scenarios designed to approximate the real-world stresses of combat. As with VR, this approach has both strengths and limitations. Although anecdotal evidence suggests good face validity and favorable RTD generalizability, scenario-based training lacks the precise measurement and repeatability of instrumented laboratory-based assessment techniques. Also, like VR, implementation of this approach requires signif-

icant resources, including costly technology, substantial logistical support, a large dedicated clinical staff, and numerous staff member hours to coordinate and execute. Thus far, assessment modules have not yet been standardized across sites, and test psychometrics have not yet been established.

Another RTD assessment approach seeking to bridge the sensitivity of laboratory measures with the ecological validity of scenario-based techniques uses militarized functional clinical test tasks. Although many DoD providers have sought to objectively quantify performance on specific warrior tasks (such as time to don a protective mask or time to complete a road march below a specified symptom severity level), such efforts have been neither standardized nor validated and likely lack the complexity to discriminate duty readiness. To address such limitations, recent efforts by a team of military and civilian rehabilitation scientists have led to the development of a novel battery of militarized dual tasks and multitasks designed to challenge known mTBI-related vulnerabilities. This battery, known as the Assessment of Military Multitasking Performance (AMMP), represents a preliminary attempt to incorporate complex clinical testing methods into RTD assessment and illustrates a potential application of the standards-based assessment paradigm in a clinical environment.⁴⁰ The AMMP integrates dual-task and multitask paradigms previously described in the literature with functional military requirements to create individual test tasks able to probe the broad range of duty-limiting symptoms and deficits associated with mTBI (Table).⁵²⁻⁶¹ Although the AMMP’s ability to discriminate duty readiness in service members with mTBI has not yet been validated and the reliability of the individual test tasks has yet to be reported, sim-

ilar procedures have been successfully applied in the assessment of athletes with concussion and mTBI.^{35,36,62-64} Clinical measures may have an added benefit of superior feasibility in remote or CONUS-based military treatment facilities relative to more resource intensive approaches described previously.

Given the importance of defeating ceiling effects associated with impairment-based clinical measures, the adoption of a more complex RTD assessment approach such as one using dual-task and multitask methods is appealing for evaluating service members with mTBI. Multitask assessment methods are used with success by clinicians with patients recovering from moderate TBI and mild stroke to tax multiple cognitive demands. Multitask scenarios provide semistructured challenges of problem-solving and organization skills required in daily routines and work activities but have not been examined in mTBI.⁵⁷⁻⁶⁰ Dual-task activities tested in laboratory contexts following mTBI show impairments when a combination of skills must be performed simultaneously (eg, cognitive task while walking), even when symptoms have apparently “resolved.”^{63,65} These same abilities, when tested separately, appear comparable to those of controls who are healthy, suggesting it may be important to test in dual-task conditions to uncover subtle mTBI impairments. Dual-task and multitask approaches provide ways to probe activity- and participation-level performance in service members with mTBI, although military-specific tasks have not been described in the literature. In the following sections, characteristics and evidence supporting each approach are highlighted to provide an overview of their potential prognostic utility and clinical feasibility in assessing service members with mTBI.

Returning Service Members to Duty Following Mild Traumatic Brain Injury

Table.

Assessment of Military Multitasking Performance (AMMP)^a

AMMP Task	mTBI-Related Vulnerabilities/ Task Demands	Task Description	Assessment Metric	Task Rationale	Published Sources and Stakeholder Inputs Contributing to Task Design
Illinois Agility Test (dual task)	Memory, attention, dynamic stability, and agility	Single task (motor): running distance of 9.1 m (30 ft) with rapid direction changes and navigation of serpentine obstacles. Single task (cognitive): 7-word list memory task. Dual-task condition: agility task and the memory task are done at the same time.	Accuracy of memory recall and time to complete the agility task are measured in single and dual-task conditions. Dual-task costs for cognitive and motor components.	Tests of walking with dual-task performance are unlikely to identify discernible dual-task costs. Service member demand for speed and agility during quick maneuvers while attending to other information supports this high-level balance, running, and working memory task.	Getchell (1979) ⁵³ McCulloch et al (2009) ⁵⁵ Hyndman et al (2006) ⁶¹
Step initiation–Stroop test (dual task)	Executive function, reaction time, and balance	Single-task condition: service member initiates forward and backward steps in response to a vibratory stimulus to the stepping leg. Dual-task condition: stepping trials performed in conjunction with a modified visual Stroop test.	Step initiation time, foot lift time, and step time in single-task and dual-task conditions.	Testing paradigm allows for sensitive measurement of reaction time, susceptible to mTBI. Vocational importance of quick responsiveness to sensory stimuli supports this task.	Melzer et al (2007) ⁵⁶
Radio chatter–magazine load (dual task)	Executive function, attention, and manual dexterity	Single task (motor): service member loads simulated M-16 rounds into an ammunition magazine. Single task (cognitive): service member identifies discrete audio cues on a simulated radio transmission. Dual-task condition: loading magazine while listening to simulated radio broadcast.	Number of cognitive errors (omission, commission) and number of rounds loaded in single-task and dual-task conditions.	A dual-task scenario using a manual task and a cognitive task demonstrated mTBI deficits. The requirement to hear and identify relevant information on a tactical network while performing bimanual dexterity tasks is functionally significant.	Cicerone (1996) ⁵²
ISAW-grid (dual task)	Memory, attention, gaze stability, balance, and dynamic stability	Single task (motor): instrumented postural sway and gait assessment. Single task (cognitive): 8-digit alphanumeric grid coordinate memory task. Dual-task condition: instrumented sway and gait measures while performing memory task.	Accuracy of memory recall, postural sway area, gait path variability, and time for completion in single-task and dual-task conditions.	Preliminary testing of individuals postconcussion using this paradigm has been reported. The importance of maintaining postural and dynamic stability in activities of daily living is fundamental to all other functional tasks, behaviors anecdotally susceptible to effects of blast exposure. This task utilizes accelerometry, sensitivity that may be necessary to identify movement aberration resulting from mTBI.	Mancini et al (2012) ⁵⁴

(Continued)

Returning Service Members to Duty Following Mild Traumatic Brain Injury

Table.
Continued

AMMP Task	mTBI-Related Vulnerabilities/ Task Demands	Task Description	Assessment Metric	Task Rationale	Published Sources and Stakeholder Inputs Contributing to Task Design
SALUTE (multitask)	Executive function, attention, memory, visual scanning, gaze stability, and exertion	Service member is challenged to gather information from video surveillance recordings and radio communication recordings (SALUTE) while performing a continuous modified step test at >65% of age-predicted maximum THR.	Accuracy/errors of SALUTE report; ability to maintain appropriate exertional load.	The ability to integrate and retain in one's working memory visual and auditory stimuli that are operationally significant under exertion represents a high level of functional readiness in a clinical environment in a task that is clearly relevant to a service member.	Warrior Resiliency and Recovery Center, Fort Campbell, Kentucky Developed to address key vulnerabilities not addressed with existing methods
Run, roll, aim (multitask)	Attention, smooth pursuit tracking, dynamic stability, exertion, vertical gaze stability, and monocular vision	Service member completes a high-level mobility task with multiple visually cued maneuvers while carrying a simulated weapon. Rapid start, obstacle (trip wire) avoidance, 3- to 5-second rush, dive to a prone position, combat rolling. Visual target selection through weapon scope, rapid lateral dodging and back pedaling.	Total time for complex task completion with penalties for errors; accuracy of visual target identification; head-mounted inertial sensor measures of acceleration and angular velocity for movement components.	The ability to execute individual movement techniques may provoke vestibular symptoms, known to be an issue following mTBI. Intermittent visual search via weapon scope and fast position changes challenges sensory stability and motor performance at a high level of functional performance in a task that is clearly relevant to a service member.	Warrior Resiliency and Recovery Center, Fort Campbell, Kentucky Developed to address key vulnerabilities not addressed with existing methods
CQ duty (multitask)	Executive function, memory, and visual scanning	Service member organizes and performs an array of interleaving tasks associated with a hypothetical assignment to staff duty, including communicating information via radio at the beginning, middle, and end of the task; assembling a footstool for an injured service member; filing a duty log; and obtaining additional information from wall charts. Following directions for additional subtasks, and radio when the exercise is completed. A prospective memory task also is incorporated into the CQ duty scenario.	Number of subtasks completed accurately. Number and types of errors and rule breaks. Number of transits between the 4 workstations to complete the task. Overall performance time required to complete the task.	This task requires planning a series of subtasks that dovetail with each other to accomplish the goal in the most efficient way, requiring executive function. Working memory requirements are integrated throughout the task.	Alderman et al (2003) ⁷⁷ Burgess (2000) ⁵⁹ Burgess et al (2006) ⁶⁰

^a mTBI=mild traumatic brain injury; ISAW=instrumented stand and walk; SALUTE=Size, Activity, Location, Unit, Time, Equipment report; THR=target heart rate; CQ=charge of quarters.

Dual-Task Performance

Dual-task assessment methods require an individual to perform a primary task while simultaneously performing a secondary task, with combined performance compared

with one's baseline performance in each single-task condition.⁶⁶ In this context, a motor task with a secondary cognitive task is a reasonable combination. Reduction in performance of a task when executed in

conjunction with a secondary task is termed the *dual-task cost* (eg, cost in time or in number of errors) of performing 2 tasks simultaneously. The interpretation of dual-task paradigms follows the view that human

processing resources are limited and capacity must be shared to accomplish both tasks, often resulting in dual-task performance costs.⁶⁷

Many studies have revealed accentuated deficits in dual-task abilities following concussion and mTBI during postural control tasks acutely, with impairments sometimes persisting several months postinjury.^{35,36,62} These dual-task costs are significantly greater than those observed in age-matched controls and are influenced by environmental and visuospatial complexity.^{62,65,68–70}

The ability to do 2 tasks at once is theorized to require executive control. Attention must be allocated appropriately to perform both tasks successfully. Laboratory studies using cognitive dual tasks reveal slower reaction and response times and increased cognitive task error following sports concussions.^{70–72} Additionally, difficulty with dual tasks or an inability to perform such tasks is associated with safety problems and may not be evident if motor or cognitive tasks are assessed singly and not in combination.^{62,65} Individuals with concussion and mTBI and those with more severe acquired brain injury show consistent difficulty with dual-task performance of cognitive and motor tasks in laboratory dual-task paradigms and clinical tests during walking.^{67,70,73} After concussion, dual-task costs have been documented in walking speed, variability, and stability. The ability to orient, allocate attention to, and switch focus between visual stimuli is impaired, which is correlated with problems with obstacle avoidance while walking.^{62–64,70,74,75} Higher-level balance deficits, vestibular injury, or musculoskeletal injury may contribute to these performance problems. These dual-task gait deficits have been observed to persist over longer time frames than cognitive deficits after concussion and

could influence mobility on uneven terrain.^{35,76}

Dual tasks that have been used clinically include memory tasks executed during walking and running conditions. One example of a dual task formulated to challenge a military service member population could involve administering the Illinois Agility Test (which requires rapid direction changes and obstacle avoidance, consistent with service member physical training activities) while performing a secondary cognitive task to challenge dynamic stability, agility, and cognitive function simultaneously.⁴⁰ Most studies of dual-task performance postconcussion also have used sensitive instrumentation to capture what are sometimes small changes in postural control. Dual-task scenarios tailored to service members could be designed in a similar way by using compact technologies (eg, inertial sensory measures) to improve measure sensitivity in forward-deployed or remote environments where safe and timely RTD decisions are most critical.

Multitask Observational Performance

Competence in everyday life requires the ability to multitask, using multiple cognitive and motor abilities to plan, organize, and carry out complex tasks (Box 3). Standardized testing of multitask performance is used in occupational therapy and neuropsychology to approximate the demands of a real-world environment (ie, role engagement) and is valued for its ecological validity.^{57,60} Planning, organizing, and problem solving, governed by executive function, are required during a multitask assessment. The evaluator observes performance for *errors in action* while a patient is given free rein to perform prescribed multistep everyday tasks that involve

an array of multiple objects, task demands, and rules.⁵⁷

Box 3. Burgess' Definition of Multitasking describes 5 features that are commonly included in performance-based multitask assessments.

- Many tasks:** Numerous separate and varied tasks are completed.
- Interleaving:** Tasks are dovetailed (ie, alternated or coordinated in accordance with a plan).
- Only one task performed at a time:** Tasks are performed one at a time due to either cognitive or physical constraints, further reinforcing interleaving.
- Interruptions and unexpected outcomes:** Tasks are dynamic and may have unanticipated interruptions or situations where things do not go as originally planned.
- Delayed intentions:** Tasks require a person to remember to do a second thing, unrelated to the successful completion of the overall multitask (referred to as a "prospective memory" requirement).

Performance-based multitask assessments have been developed that focus on frontal lobe dysfunction that occurs with stroke and TBI.^{57,77} These assessments reveal common problems with multitasking across the spectrum of patients with neurologic involvement from subtle deficits after mild stroke to more significant cognitive deficits following moderate to severe TBI.^{65,67,70,78–80} Without exception, the multitask scenarios described in the literature lack face validity for the military population; they require instrumental activities of daily living such as simple cooking tasks or telephone use (Naturalistic Action Test [NAT], Executive Function Performance Test), wrapping a present (NAT), or running errands in a mall or hospital setting (Multiple Errands Test). Although these assessments evaluate high-level executive functioning deficits and require prioritization of tasks, switching sets, and prospective memory, such metrics are not reflective of military vocational demands.

Effective multitasking is essential during combat operations. A report

by Fischer and Mautone⁸¹ on multitasking requirements in military environments suggests that environments vary along 3 main dimensions: type of multitask required (decision making, information monitoring, and task-flow management), intensity of multitask, and consequences of failure. Multiple sensory, motor, and cognitive systems contribute to successful multitasking skills, systems that may be compromised following mTBI.

Service members may perform well on impairment-based assessments that evaluate single-component processes in nondistracting and non-stressful environments. Performance deficits become evident when tasks are presented with less structure and increasing difficulty, requiring real-time decision making and the effective allocation of cognitive, physical, and sensorimotor resources across multiple simultaneous demands. Anecdotally, service members who are successful in performing isolated cognitive, physical, and sensorimotor tasks (eg, BESS, ANAM, ImPACT) often report a sense of feeling “off” when similar challenges combine within the multidimensional demands that are critical to most service members’ duties or to complex family life situations when in garrison.

Theorized military multitask scenarios should focus on the multisystem vulnerabilities associated with concussion and mTBI. Examples of multitask formulations that may prove useful in discriminating RTD readiness have recently been described.⁴⁰ One such measure challenges a service member to observe, process, and retain relevant information from a customized, computer-generated mission scenario while continuously stepping on an exercise step at a moderate pace. This task combines physical exertion with a demand for vigilance or “situational awareness”

during a simulated dismounted patrol in a way that approaches the real-world demands on a member of a reconnaissance patrol in deployed environment. Although highly realistic computer graphics and meticulously scripted scenario content allow an examiner to target known mTBI-related vulnerabilities, this assessment differs from more sophisticated VR approaches in its simplicity and clinical feasibility. The task can be projected to any treatment environment that will support a computer monitor and an exercise step (with or without inertial sensor data collection). Another task approximates the physical agility required for military individual movement techniques while intermittently challenging visual sensory stability and attention to detail (verbal identification of targets) during target sighting through a simulated weapon scope. Demands of this test task are consistent with rapidly changing physical, sensory, and cognitive demands in a combat environment.

Conclusion

Determination about service members’ readiness to RTD following mTBI is still informed primarily by a patient’s self-report of symptoms and by clinical tests that assess performance within distinct body structure or function domains. Widespread adoption of a theoretical framework that measures service member fitness for duty at the activity or participation level would be highly desirable to improve prognostication of real-world warfighting performance. General acceptance of a paradigm that conceives of an individual’s *readiness*, not as the absence of impairments but as a vector-sum of military competencies, represents an important ideological shift from what a member *cannot* do, to what he or she *can* do. Although this type of standards-based construct may be difficult to quantify using conven-

tional impairment-based testing, complex assessment methods should help to bridge this assessment gap.

Measures of postconcussive functional performance emerging to address RTD assessment challenges within the DoD include immersive virtual environments; field or scenario-based programs; and clinical tests incorporating dual-task and multitask methods. Although each of these approaches has relative strengths and limitations, all are challenged by a general lack of clarity on how to externally validate duty readiness following mTBI. Absence of a “gold standard” benchmark of duty readiness within the DoD persists as much due to the complexity of factors that affect human performance following neurotrauma as to uncertainty surrounding how to measure such a multifaceted construct. Measurement may be further confounded by the expense required to install, administer, and sustain technologically sophisticated or intensive assessment programs, dramatically limiting use of certain methods outside of hub military treatment facilities. Such barriers constrain the widespread feasibility of these approaches and make DoD-wide standardization of RTD metrics difficult. Development of militarized dual-task and multitask methods represent a potential solution to these practice and dissemination barriers given the relative feasibility of clinical assessment techniques, demonstrated utility of dual-task and multitask assessment in civilian patients with TBI, and their strong face validity for commanders, service members, and clinicians.^{65,67,70,73–75,79,80}

Dual-task and multitask testing methods may be more time consuming to administer than impairment-based assessments and not necessarily feasible for all environments of care.⁸² Nonetheless, their potential sensitiv-

ity to duty-limiting performance gaps could be quite valuable in remote clinical practice settings where timely and appropriate RTD determinations often are essential.

Future research efforts should continue to explore and develop standards-based criteria to guide RTD and RTP decision making, not only in the wake of mTBI but also to address the broad spectrum of potential duty- or play-limiting deficits. Standards-based metrics do not replace traditional clinical decision making by clinicians who manage patients and their injuries. Such methods provide military clinicians with additional data points for evaluating abilities more clearly related to functional occupational demands. This approach ultimately benefits the service member, the unit, and the military as a whole by verifying that a returning service member is not only symptom-free but truly “duty ready.”

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