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 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 simultaneously[33] (evidence of executive dysfunction[34]), 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 living[37] 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 Assessment[40] 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).

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

a

Stakeholder.

b

Researcher.

c
End user.

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 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.

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.

Key Areas of Input	Interview Findings and Impressions
	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.

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.

TABLE III

Multitasks and Dual Tasks Comprising AMMP Version 1.0

Task/Test*a*	mTBI Symptom Domains										
	Cognitive				Sensory			Physical			
	Executive Function	Memory	Attention	Reaction Time	Eye Gaze Tracking	Scanning	Vestibular	Balance	Exertion	Bend-Lift	Manual Speed
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			○		•		•	•	○		

Task/Test[a]	mTBI Symptom Domains										
	Cognitive				Sensory			Physical			
	Executive Function	**Memory**	**Attention**	**Reaction Time**	**Eye Gaze Tracking**	**Scanning**	**Vestibular**	**Balance**	**Exertion**	**Bend-Lift**	**Manual Speed**
"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	•			•				○			

Task/Test[a]	mTBI Symptom Domains										
	Cognitive				Sensory			Physical			
	Executive Function	Memory	Attention	Reaction Time	Eye Gaze Tracking	Scanning	Vestibular	Balance	Exertion	Bend-Lift	Manual Speed
Load magazine/radio chatter dual task	○		•								•

a

mTBI-related task challenges: primary, •; secondary, ○.

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 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 Assessment[40] 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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