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

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Abstract:

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.

Over the last decade, in excess of 220,000 military service members have sustained a 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 noncombat 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 firefighting 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

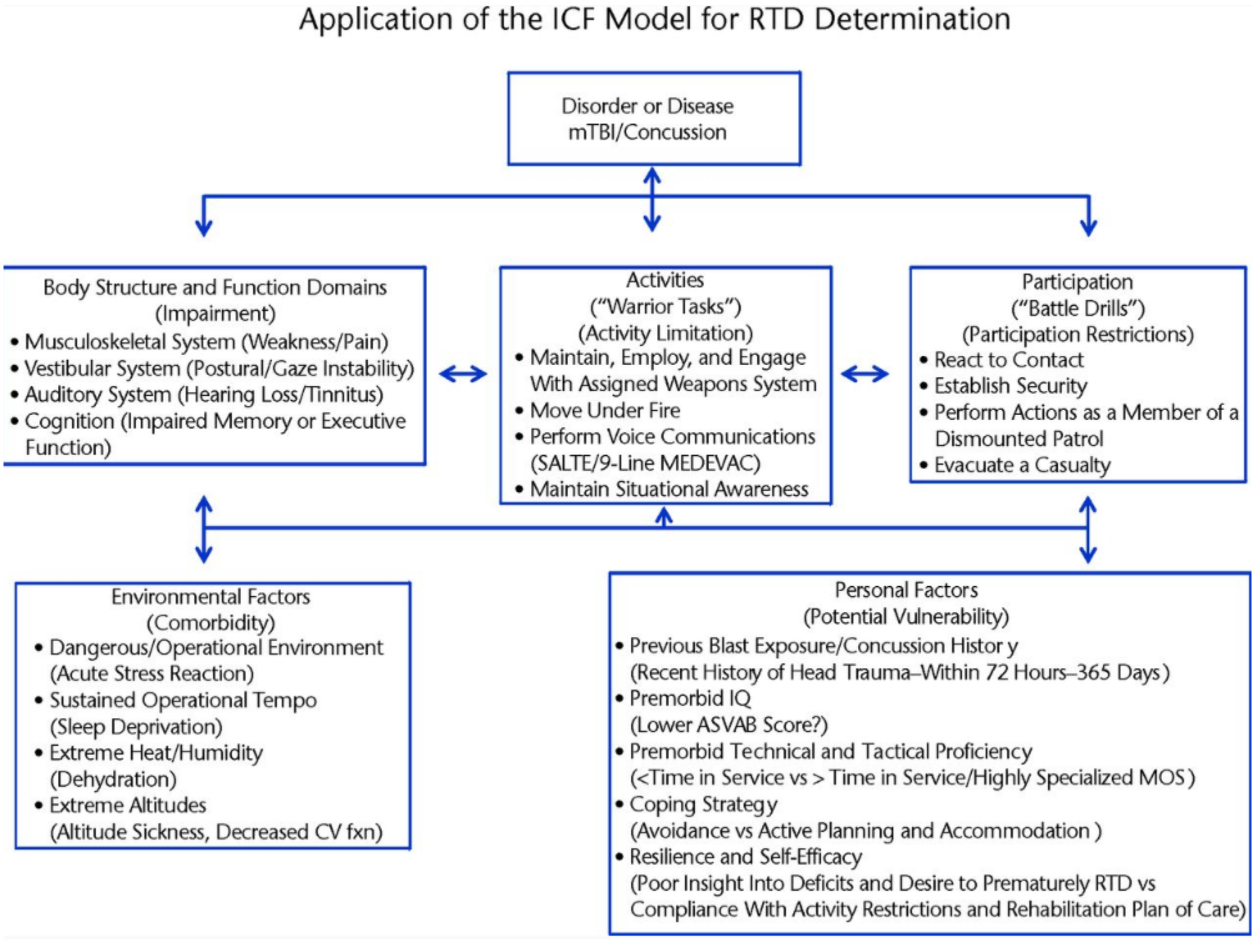
The previous section highlighted a number of symptoms and impairments believed to degrade duty readiness. However, in addition to symptoms of physical discomfort, sensory instability, or disorientation, acutely concussed personnel may experience activity- or participation-level performance deficits in 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

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.

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 theoretical 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.

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 significant 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, similar 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.

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

AMMP Task	mTBI-Related Vulnerabilities/ Task Demands	Task Description	Assessment Metric	Task Rationale	Published Sources and Stakeholder Inputs Contributing to Task Design
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	Number of cognitive errors (omission, commission) and number	A dual-task scenario using a manual task and a cognitive	Cicerone (1996)52

AMMP Task	mTBI-Related Vulnerabilities/ Task Demands	Task Description	Assessment Metric	Task Rationale	Published Sources and Stakeholder Inputs Contributing to Task Design
		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.	of rounds loaded in single-task and dual-task conditions.	task demonstrated mTBI deficits. The requirement to hear and identify relevant information on a tactical network while performing bimanual dexterity tasks is functionally significant.	
ISAW-grid (dual task)	Memory, attention, gaze stability, balance,	Single task (motor): instrumented postural	Accuracy of memory recall, postural	Preliminary testing of individuals postconcuss	Mancini et al (2012)54

AMMP Task	mTBI-Related Vulnerabilities/ Task Demands	Task Description	Assessment Metric	Task Rationale	Published Sources and Stakeholder Inputs Contributing to Task Design
	and dynamic stability	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.	sway area, gait path variability, and time for completion in single-task and dual-task conditions.	ion 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	

AMMP Task	mTBI-Related Vulnerabilities/ Task Demands	Task Description	Assessment Metric	Task Rationale	Published Sources and Stakeholder Inputs Contributing to Task Design
				necessary to identify movement aberration resulting from mTBI.	
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	Warrior Resiliency and Recovery Center, Fort Campbell, Kentucky Developed to address key vulnerabilities not addressed with existing methods

AMMP Task	mTBI-Related Vulnerabilities/ Task Demands	Task Description	Assessment Metric	Task Rationale	Published Sources and Stakeholder Inputs Contributing to Task Design
				clearly relevant to a service member.	
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	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	Warrior Resiliency and Recovery Center, Fort Campbell, Kentucky Developed to address key vulnerabilities not addressed with existing methods

AMMP Task	mTBI-Related Vulnerabilities/ Task Demands	Task Description	Assessment Metric	Task Rationale	Published Sources and Stakeholder Inputs Contributing to Task Design
		target selection through weapon scope, rapid lateral dodging and back pedaling.		level of functional performance in a task that is clearly relevant to a service member.	
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	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	Alderman et al (2003)77, Burgess (2000)59, Burgess et al (2006)60

AMMP Task	mTBI-Related Vulnerabilities/ Task Demands	Task Description	Assessment Metric	Task Rationale	Published Sources and Stakeholder Inputs Contributing to Task Design
		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		throughout the task.	

AMMP Task	mTBI-Related Vulnerabilities/ Task Demands	Task Description	Assessment Metric	Task Rationale	Published Sources and Stakeholder Inputs Contributing to Task Design
		duty scenario.			

[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.

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.

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.62–64,70,74,75Higher-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.40Most 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 multitasks (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 nonstressful 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 a 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 conventional 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 sensitivity 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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