Patient Related Outcome Measures

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ORIGINAL RESEARCH

Development of Military Concussion Readiness Inventory for Dizziness and Balance

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Purpose: The objective of this study was to develop and establish content validity of a new instrument titled the Military Concussion Readiness Inventory for Dizziness and Balance (MCRI-DB). The MCRI-DB was intended to recognize functional impairments and predict readiness for return-to-duty in service members who experienced mild traumatic brain injury (mTBI).

Methods: Nineteen male service members were included in a nominal group technique (NGT) process to produce items for the MCRI-DB. Items were categorized according to the International Classification of Functioning, Disability and Health (ICF) and were sent to 13 physical therapy experts through a Delphi survey to determine content validity. The consensus to include an item was defined as an agreement of at least 70% of the participants.

Results: The NGT produced 222 items with 108 duplicates removed. The ICF categorization linked 84 of the items to 36 unique ICF Codes, 9 items were not linkable to the ICF due to the complex nature of the activity, and 21 items were removed. After three rounds of the Delphi survey, 68 items were included in this instrument.

Conclusion: In this study, we successfully combined the use of service members' experiences with expert opinion to determine content validity of the MCRI-DB. This instrument may be used for assessment of service members who have experienced mTBI to help identify environmental factors, functional activities, and body functions that may reduce the safe and efficient fulfillment of their duties and determine their ability to return-to-duty. Further research is needed to develop the psychometric properties of the instrument fully.

Keywords: blast injury, questionnaire, return-to-duty, service member

Introduction

Traumatic brain injuries (TBI) secondary to blast or explosions are the most represented means of injury seen in Iraq and Afghanistan,[1–7] and have been described as the "signature injury" of service members.[2,6] TBI can be categorized as concussion/mild, moderate, severe, or penetrating/open.[8,9] According to the Defense and Veterans Brain Injury Center (DVBIC), concussion or mild TBI (mTBI) is the most common category of TBI among all service members of all branches of the military including active duty, reservists, National Guard, and veterans.[8,10] The Department of Defense (DoD) describes mTBI as including one or more of the following conditions: loss of consciousness lasting up to 30 minutes, disorientation or confusion lasting less than 20 hours, altered state of consciousness for less than 20 hours, loss of memory lasting less than 24 hours with normal structural imaging.[7,9] The DVBIC have reported that 379,519 service members have received some form of TBI since 2000, with the number of mTBI at 312,495.[8] These numbers only represent service members who

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have self-reported the injury or were medically evacuated.[2,7] The mTBI numbers may be low because service members may be unwilling to report symptoms of mTBI until after deployment or later in their medical care. This reluctance may be related to the service members not wanting to be detached from their unit.[7,10]

The principal causes of mTBI in service members are from motor vehicle accidents, falls, blasts, fragments, and bullets.[9] Previously, it was believed that a blast injury results in a more global and bilateral injury pattern, resulting in difficulty with postural stability and inability to adapt to perturbations.[11] It is now evident that there is no indication to propose significant differences between the blast and blunt brain injury.[10] mTBI commonly result in gaze instability (ie, inability to see clearly with head movement), complaints of vertigo, unsteadiness of balance, and motion intolerance.[2] Service members with mTBI may have continued dizziness and/or imbalance preventing their ability to perform their duties of work.[2]

Investigators have recognized detailed recommendations for physical therapy evaluations for service members with mTBI.[2,5,7] The physical examination should focus on improving the functional deficiencies that are identified in the history and review of systems. Recommended clinical tests contain examination of the vestibular function (eg, head impulse testing, dynamic visual acuity, and Dix–Hallpike),[7,11,12] the balance function (eg, computerized sensory organization test[7,13] and Functional Gait Assessment),[7,14] dual-task performance and attention,[7,14–16] activity intolerance, and examination for neck or temporomandibular joint function and headache.[7]

Along with the physical examination, subjective questioning of a service members' self-perceived functional ability is also imperative. Several different instruments (eg, Activities-specific Balance Confidence [ABC] scale[17] and Dizziness Handicap Inventory [DHI])[12,18] are used to measure subjective function. These tools are not suitable to determine impairments[4] specific to the activities that service members perform. The ABC is a reliable test used to measure confidence in balance in elderly adults;[17] however, this 16-item scale may lack the sensitivity to determine higher level functional impairments. The DHI is also a reliable test used to assess self-perceived disability owing to dizziness. This test is also not adequate to determine impairments of service members. Weightman et al[7] report that there is currently no instrument that measures participation and reintegration to a military lifestyle, so there is a tendency to use a global measure such as the 36-item Short Form Health Survey (SF-36)[19] for this population until a military participation instrument is developed. Scherer et al also reported that further exploration is required to develop an adequate instrument to assess service members with mTBI.[4] The service members deficits from mTBI may be very subtle but of sufficient magnitude, as to limit their ability to perform their full military requirements. Therefore, a tool with job-specific tests needs to be developed for the military population. The nominal group technique (NGT) and Delphi technique are appropriate methods to develop and establish content validity of an instrument intended to assess functional deficiencies in service members who experience an mTBI.[20–32]

The purpose of this study was to create and determine content validity of a new instrument titled the Military Concussion Readiness Inventory for Dizziness and Balance (MCRI-DB) to recognize functional impairments of dizziness and balance in service members who experienced an mTBI. This questionnaire may also predict readiness for return-to-duty after such injury. The items on the MCRI-DB will also be classified/linked to the International Classification of Functioning, Disability and Health (ICF) to determine the variation within a domain better and allow a standard language to compare between studies.

Methods

The study was approved by the Institutional Review Boards of William Beaumont Army Medical Center (WBAMC) and The University of Alabama Birmingham (UAB) (protocol number: X110802008). Written informed consent was received from all participants. The NGT data were collected between May 2012 and June 2012,[1] and the Delphi survey data were collected between August 2012 and November 2012.

Nominal group technique

The NGT facilitates decision-making in the identification and ranking of problems, and promotes equal participation from group members in a face-to-face meeting.[20–23]

An NGT was utilized to generate items for the MCRI-DB. Service members were enlisted for one of two groups: the "blast group" and the "non-blast group." The "blast group" participants included service members who have been diagnosed with a concussion from a blast injury in the Warrior Care Center–TBI Clinic at WBAMC. These participants must also have experienced dizziness and/or imbalance due to the blast injury. The "non-blast group" included service members who have not been diagnosed with an mTBI. The inclusion of the "non-blast group" was to account for those service members who might not report their injury to medical providers. These service members in the "non-blast group" may be

experiencing these difficulties themselves or observing the difficulties other service members have after concussions.

Enlistment for the blast and non-blast participants occurred through flyers that were displayed in the TBI and physical therapy clinics at WBAMC. Patients who were seen in the TBI clinic and had a diagnosis of a concussion with dizziness and/or imbalance from a blast injury were referred by TBI medical providers for the "blast group." At the medical visit, prospective participants were informed that they might qualify for the research study. If the patient was interested in being a participant, the service members met face-to-face with the Principal Investigator (PI) for the consenting process.

The "non-blast group" was enlisted by face-to-face recruitment by the PI at Fort Bliss and White Sands Missile Range (WSMR). The primary investigator met with the service members to discuss the study and obtain voluntary informed consent.

All service members who were included in the blast and non-blast groups ambulated independently and were between the ages of 19 and 50 years. Exclusion criteria included having a cardiac disorder that causes dizziness, having any other neurological disorders, such as a seizure disorder, not able to speak English proficiently, cognitive impairment, or uncontrolled psychiatric conditions. Nominal groups were arranged by the investigators into the "blast group" and "non-blast group."

Four nominal group meetings of 4–5 service members lasting approximately 1 hour and 50 minutes each were held. The PI facilitated the meeting and was assisted by a student physical therapist (PT) who was responsible for recording the responses that the group generated. The nominal group members were requested to share their opinions about the following two questions regarding military tasks: 1) what military or non-military tasks do you think will be difficult to perform due to balance trouble in someone who has had a blast injury? and 2) what military or non-military tasks do you think will cause or increase dizziness in someone who has had an mTBI injury? The participants were provided time to write their thoughts before sharing them with the group. Group members alternated turns, without interruption, sharing their ideas until no further ideas were produced as the PT student wrote the items on the flipchart. The group then clarified the responses and removed redundant answers. At that point, each participant was asked to rate what they felt were their top five responses to each query. All four groups were conducted with the same techniques. The complete list of items that were produced from all groups was sent to all the nominal group participants so that participants could add any items they felt were not included without peer influence. This type of member checking has been implemented in many qualitative studies to clarify and make sure the outcome characterizes its contributors.[33]

Classification/linking

Linking items generated for an instrument to the ICF is frequently used as a standard reference structure for functioning and may assist to improve outcome research (Figure 1).[34–36]

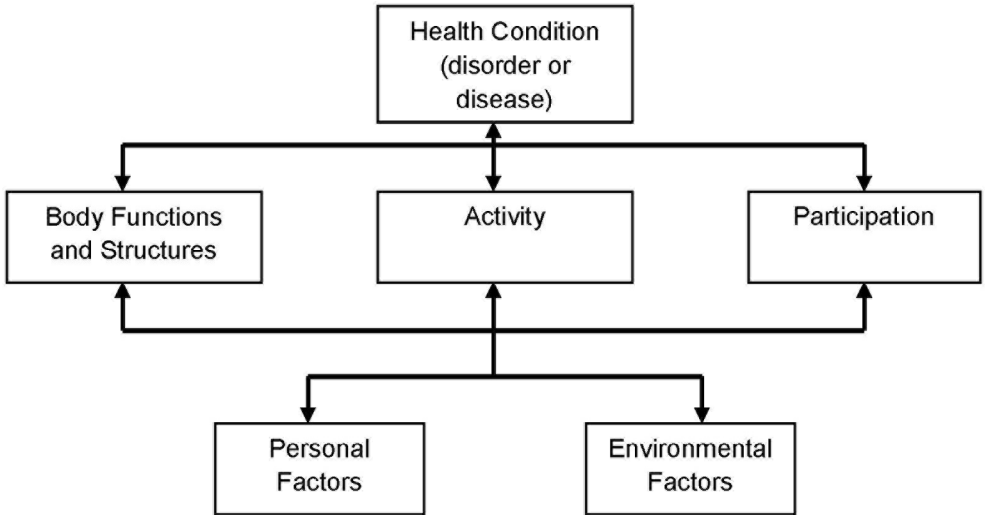

Figure 1 Interactions between the components of the ICF.
Note: Reprinted from the World Health Organization. *International Classification of Functioning, Disability and Health: ICF*. Geneva: World Health Organization; 2001. Available from: www.who.int/classifications/drafticfpracticalmanual.pdf.[36]
Abbreviation: ICF, International Classification of Functioning, Disability and Health.

This technique enables researchers to determine the change within a domain better and allows a standard language to compare among studies.

After the nominal group items had been generated, the PI combined all items between groups that described similar tasks and explained the military tasks. Collaborating investigators (JBC and SLW) categorized the items according to the ICF.[36] The items were linked to the four domains set by the ICF: body functions, body structures, activities and participation, and environmental factors.[36] The classification method included two rounds, as described in a previous study.[37] The two investigators first coded the items independently, and any differences were then discussed until both investigators decided on the classification for each item.

Delphi technique

After items were generated and linked to the ICF, content validity was established by use of the Delphi technique. The Delphi technique is a collaborative, anonymous method that includes a group of subject matter experts who deliberate on a particular subject, typically through a series of surveys to establish consensus opinions.[22,23,27,30,32] This method is useful when face-to-face meetings with opinion leaders are impossible. An advantage of the Delphi technique is that it dissuades one strong member from influencing group opinion.[22,25,29] The Delphi group members were PTs working for the military who were identified by the primary and collaborating authors. An invitation was sent to the experts explaining the study. The inclusion criteria for the subject matter experts included post-entry-level training in vestibular rehabilitation and at least 1-year experience assessing and treating service members who have blast-induced TBI.

The list of items produced by the nominal group was sent to the experts in electronic form. The experts were requested to rate each item on a four-point scale: 1) this item should definitely not be included in the questionnaire; 2) this item, although acceptable, is not necessary for the questionnaire; 3) although not essential, this item would contribute to the questionnaire; and 4) it is essential that this item be included in the questionnaire. The experts were also asked to include any other items they felt should be added to the survey.

Although there are no standard procedures for the percentage of the amount of consensus to use with the Delphi technique, 70%–80% agreement has been used in several studies as the acceptable percentage of agreement.[22,24,26,29,31] Therefore, 70% was the agreement measure that was used to determine content validity index of each MCRI-DB item.

The PT, using the predetermined 70% for agreement of either inclusion or exclusion of each item, analyzed the responses from each round. A breakdown of the experts' agreement on each round of the Delphi technique was performed, and the percentage agreement per item was determined. The scores were determined for two subgroups,[25] one for inclusion and one for exclusion. The responses "this item should definitely not be included in the measure" and "this item does not need to be included for the measure to be useful" signified "exclusion" and meant that the items should be removed. The responses "although not essential, this item would contribute to the measure" and "it is essential that this item be included in the measure" signified "inclusion" and meant that the item should remain in the final version. The items that had at least 70% agreement on the inclusion of an item were included in the MCRI-DB. For each subsequent round, the experts received the scoring of all items from the previous round. Experts were asked again to rate any items that did not meet consensus of 70% of inclusion or exclusion on the four-point scale. We also asked the experts to include any comments related to the items. We planned to continue until there was a 70% or greater agreement on all items. However, items that consistently had less than 70% consensus with no changes in responses with repeated rounds and no comments regarding the items were dropped from the Delphi survey. All answers remained confidential throughout this procedure.

Results

Nominal group

Twenty-three service members were recruited and volunteered for this study. Four were not able to participate in the scheduled meetings due to job obligations or emergency leave. Nineteen male service members participated in the nominal groups (n=10 blast; 9 non-blast). All participants were in the Army with a mean age of 32±7.5 years (ranging from 21 to 45). Participants' years in service varied from 2 to 24 years and the number of deployments ranging from 0 to 3 in the non-blast group and 1 to 8 in the blast group. No new items were generated after the third meeting, so data collection ended after the fourth meeting. The four NGT groups produced 222 total items. The PI combined all items between groups that described similar tasks and removed duplicates leaving 114 items. Member checking did not add any items to the list.

ICF classification

After the 114 nominal group items were identified, and the PI explained the military tasks, the collaborating investiga-

tors (JBC and SLW) categorized the items according to the ICF before sending the items to the Delphi group. In the first round, there was agreement by both collaborating investigators on the ICF code for 46 of the items, and there was an agreement to delete 21 more items. The deleted items were thought to be too broad of a category (eg, Virtual Training Simulators, Air Operations, Real World Combat Missions), were already included in other items (eg, Physical Readiness Training), or would cause dizziness in most individuals, not just those with blast injuries (eg, tasers, spinning in a chair, hitting the head). Agreement was not obtained for 47 items, so these were discussed until agreed upon categories were found. Consensus was attained on the remaining 93 items for the Delphi group. The resultant 93 items were linked to 36 different ICF codes describing pertinent features of functioning (Tables 1 and 2). Fifty-four of the items were linked to the component of activity and participation, 14 of the items were linked to the component body functions, 10 to the component environmental factors, 6 items met the criteria for multiple ICF categories, and 9 items were not linkable to the ICF due to the complexity of the activity itself. None of the items were linked to the body structures category of the ICF.

Delphi group

Eighteen subject matter experts were recruited, and 14 agreed to participate. The experts included 11 female and 3 male PTs ranging in age from 29 to 57 years with a mean age of 37±7.6 years. There were five PTs who were in active duty, five PTs were civilians, three PTs were reservists, and one PT was retired from service. Experience of these 14 PTs ranged from 6 to 35 years. Ten of the experts treat Army service members primarily, and three treat Marine and Navy service members, while one treats service members from all branches of the military. All of the experts were currently or within the last one year working with service members with TBI. Thirteen experts completed two rounds of the Delphi survey, and one was lost to deployment, while ten participants completed the third round.

After the first round, there was an agreement to include 56 of the items and agreement to exclude two items. The second round consisted of 35 items that did not meet the 70% consensus rule in the first round. After the second round, there was at least 70% agreement to include six further items and to exclude nine items. The third round consisted of 20 items that did not reach consensus in round two. After round three, there was at least 70% agreement to include six additional items and to exclude one item (Figure 2). The Delphi survey was stopped after three rounds because there was little change in reaching 70% consensus, and no suggestions were made by the experts to modify any of the 13 remaining items.

Sixty-eight items comprise the MCRI-DB (Table S1). These 68 items include ICF concepts from activity and participation, body functions, and environmental factors. There were no items included from body category of the ICF. The final survey items ranged from light activities such as reading or looking up to high functional activities including running, jumping, or wearing gear/combat load. Most of the items were linked to activities and participation concepts.

Discussion

In order to attempt to recognize functional impairments and predict readiness for return-to-duty in service members who have experienced a blast-induced mTBI, the MCRI-DB was developed. This study identified 68 items believed to be significant to service members who have experienced an mTBI. The 68 items were approved by subject matter experts who agreed that the items should be included in the MCRI-DB.

Even though a service member may have impairments in many areas of function following mTBI due to a blast injury, the questions examined in the NGT were limited to dizziness and balance. The purpose of the measure was to place emphasis on these functional and physical components of the evaluation. The precise line of questioning during the NGT reinforced the service members to provide items related to activities and participation, body functions, and environmental factors.

To establish a patient's baseline, questionnaires are used in physical therapy evaluations. Questionnaires can help to focus the assessment and intervention, and determine readiness for discharge. Determining the self-perceived disability due to dizziness and balance issues that a service member has while performing military duties may help to assess the readiness of a service member to return-to-work. Since we used input from service members with mTBI to develop the MCRI-DB, the instrument contains military and non-military tasks that may help predict readiness for return-to-duty.

The tests and questionnaires presently used to evaluate a service member with TBI have been validated on other populations, such as the elderly. Clinically, when the ABC is administered to soldiers who sustained TBI, particularly mTBI, service members routinely score very high or perfect scores (no deficits), but these same soldiers continue to account dizziness and balance issues while performing military duties. Service members are likely to participate in high-level activities regularly and do not tend to have difficulty with many of the items that are included in the ABC,

Table 1 Items included in the Military Concussion Readiness Inventory for Dizziness and Balance after the nominal group and Delphi group

Included items (n=68)	ICF codes	% Included	% Excluded
Body functions (n=8)			
Anxiety, worry, fear	b1522: Range of emotions	100%	0%
Migraines/headaches	b28010: Pain in head and neck	100%	0%
Sleep deprivation: waking up at early hours/working long hours >24 hours	b1340: Sleep functions	100%	0%
Over exerting/physical exertion/excessive physical activity	b455: Exercise tolerance functions	92%	8%
Tinnitus/inner ear disturbance	b2400 Ringing in ears or tinnitus	92%	8%
Nuclear biological chemical mask	b210: Seeing functions b152: Emotional functions	85%	15%
Strain/bearing down	b5250: Elimination of feces	85%	15%
Dehydration	b54501: Maintenance of water balance	77%	23%
Activities and participation (n=37)			
Abrupt movement	d410: Changing basic body position	100%	0%
Mental exertion	d240: Handling stress and other psychological demands	100%	0%
Riding in military vehicle/enclosed vehicles	d4709: Using transportation, unspecified	100%	0%
Running	d4552: Running	100%	0%
Standing in formation	d4154: Maintaining a standing position	100%	0%
Uneven surfaces	d4502: Walking on different surfaces	100%	0%
Walking in crowds	d469: Walking and moving, other specified and unspecified surfaces	100%	0%
Walking a straight line	d469: Walking and moving, other specified and unspecified surfaces	100%	0%
Adrenaline rushes, stress	d240: Handling stress and other psychological demands	92%	8%
Bending/reaching beyond neutral	d4105: Bending	92%	8%
Combat load/wearing gear	d4303: Carrying on shoulders, hip, and back	92%	8%
Drill and ceremony (D & C)	d4502: Walking on different surfaces	92%	8%
Driving	d4751: Driving motorized vehicles	92%	8%
Picking things off the ground	d4105: Bending	92%	8%
Maintaining equip/vehicles	d4550: Pulling d4551: Pushing	92%	8%
Obstacle course	d455: Moving around	92%	8%
Ruck marching	d4501: Walking long distances d4303: Carrying on shoulders, hip, and back	92%	8%
Sprinting with quick stops	d4552: Running	92%	8%
Dismounting vehicles in gear	d455: Moving around	85%	15%
Driving during the night	d4751: Driving motorized vehicles	85%	15%
Getting up (bed, chair, toilet)	d410: Changing basic body position	85%	15%
Getting in/out of bed	d4100: Lying down	85%	15%
Navigate on rough terrain	d4502: Walking on different surfaces	85%	15%
Walking/hiking narrow paths	d4509: Walking, unspecified	85%	15%
Climbing	d4551: Climbing	83%	17%
Sports: basketball/volleyball/football	d9201: Sports	80%	20%
Sports: surfing/snow/wake boarding/skate boarding	d9201: Sports	80%	20%
Carrying heavy objects	d430: Lifting and carrying objects	77%	23%
Clearing houses	d2402: Handling crisis	77%	23%
Facing backward while flying	d4709: Using transportation, unspecified	77%	23%
Firing large caliber weapons/missile firing	d4308: Lifting and carrying, other specified	77%	23%
Jumping (trampoline)	d4553: Jumping	77%	23%
Riding in the back of vehicles	d470: Using transportation	77%	23%
Traveling (trains/planes/auto/bus/boat)	d470: Using transportation	77%	23%
Walking down/up stairs	d4551: Climbing	77%	23%
Wearing advanced combat helmet (ACH)	d4304: Carrying on the head	77%	23%
Clearing obstacles	d455: Moving around	70%	30%

(*Continued*)

Table 1 (Continued)

Included items (n=68)	ICF codes	% Included	% Excluded
Environmental factors (n=10)			
Alcohol/drugs/medication	e1101: Drugs	100%	0%
Busy vision (transitioning through a change in light, looking at busy background)	e2401: Light quality	100%	0%
Flash bangs (loud noises and bright lights)	e250: Sound e2400: Light intensity	100%	0%
Flashing lights	e2400: Light intensity	100%	0%
Sound	e250: Sound	100%	0%
Confined areas (rooms/vehicles)	e299: Natural environment and human-made changes to environment, unspecified	85%	15%
Excessive light	e2400: Light intensity	85%	15%
Heat	e2250: Temperature	85%	15%
Staring at TV/computer	e2400: Light intensity e2401: Light quality	77%	23%
Altitude/elevation (combined with high altitude/elevation)	e2100: Land forms e2252: Atmospheric pressure	70%	20%
Multiple ICF categories (n=5)			
Land navigation	b140: Attention functions d4502: Walking on different surfaces d4551: Pushing	100%	0%
Food/caffeine (too much/too little)	b5153: Tolerance to food e1100: Food	92%	8%
Reading	d166: Reading b2100: Visual acuity functions	92%	8%
Rifle marksmanship/shooting a weapon	d4102: Kneeling d430: Lifting and carrying objects d450: Walking b140: Attention functions	92%	8%
Playing video games	b210: Seeing functions d4402: Find hand use: manipulating	80%	20%
Unable to be coded to a specific ICF code (n=8)			
Looking up	Not coded	100%	0%
Moving the head with eyes closed	Not coded	100%	0%
Using gym equipment	Not coded	100%	0%
Heights	Not coded	92%	8%
Turning around	Not coded	92%	8%
Mounted gun turrets	Not coded	85%	15%
Night vision goggles (NVG)	Not coded	83%	17%
Multiple transition colors	Not coded	77%	23%

Abbreviation: ICF, International Classification of Functioning, Disability and Health.

such as "walk around the house" or "sweep the floor."[17] As revealed by the service members, who contributed to the NGT, there are numerous high-level activities that service members who have experienced a blast-induced mTBI have difficulty carrying out. The MCRI-DB includes high-level activities such as running, climbing, showering, looking up, driving, sports, carrying heavy objects, carpentry, and swimming that are not included in the ABC. Items on the ABC have been linked to the ICF.[24] There were 20 items linked to activities and participation concepts and three to body functions, while no items were linked to environmental factors or body structures concepts in the ABC. The ABC is more limited than the MCRI-DB in the concepts included from the ICF and in the higher level activities. An environmental scale using items from the ICF for persons with vestibular disorders has been developed that includes questions about loud noises, design of buildings, bright lights, and even crowds.[38]

The DHI is an additional instrument frequently used by clinicians to evaluate self-perceived disability due to dizziness. The DHI contains more manageable activities that populations, such as the elderly, may have trouble performing because of dizziness and also includes "more ambitious activities such as sports, dancing, and household chores" and "strenuous housework or yard work" as the highest level

Table 2 Items excluded from the Military Concussion Readiness Inventory for Dizziness and Balance following nominal group technique and Delphi group

Excluded items (n=25)	ICF codes	% Included	% Excluded
Body functions (n=6)			
Intimate relations/sex	b640: Sexual functions	60%	40%
Not eating/hunger/dehydration	b545: Water, mineral, and electrolyte balance functions	60%	40%
Not wearing proper prescription eye glasses	b2100: Visual acuity functions	50%	50%
Smells: cooking smells/smell of blood/burnt flesh	b1562: Olfactory perception	60%	40%
Watching 3D movies	b210: Seeing functions	15%	85%
Wearing eye protection	b210: Seeing functions	23%	77%
Activities and participation (n=17)			
Cleaning/housework	d640: Doing housework	15%	85%
Constructing obstacles	d430: Lifting and carrying objects	23%	77%
Construction	d6501: Maintaining dwelling and furnishing d4453: Turning or twisting the hands or arms	8%	92%
Dancing	d4106: Shifting the body's center of gravity	15%	85%
Driving long distances	d4751: Driving motorized vehicles	50%	50%
Driving through change of weather/elevation	d4751: Driving motorized vehicles	40%	60%
Grenade throwing	d4454: Throwing	15%	85%
Mowing lawn	d4502: Walking on different surfaces	8%	92%
Operating power tools	d4453: Turning or twisting the hands or arms	40%	60%
Parachute rigging	d540: Dressing	23%	77%
Picking up children	d4105: Bending	33%	67%
Showering	d510: Washing oneself	50%	50%
Swimming	d4554: Swimming	60%	40%
Rappelling	d4401: Grasping d4350: Pushing with lower extremities	60%	40%
Riding motorcycle	d4751: Driving motorized vehicles	30%	70%
Roller coasters/amusement park rides	d4709: Using transportation, unspecified	40%	60%
Wading	d4502: Walking on different surfaces	15%	85%
Environmental factors (n=1)			
Changes in temperature	e2250: Temperature	23%	77%
Unable to be coded to a specific ICF code (n=1)			
Wear MOPP (mission-oriented protective posture) gear	Not coded	50%	50%
Deleted items (n=21)			
Activities of daily living			
After an MRI			
Airborne/air assault operations			
Clearing improvised explosive device/mine sweeping			
Combatives			
Demolitions			
Environmental conditions			
Field sobriety test			
Flight duty/operations			
Hitting your head			
Keeping up with the kids			
Long power point presentations			
Medical training/mass casualty evacuation			
Physical readiness training			
Real-world combat missions			
Spatial orientation			
Spinning in chair			
Tasers			
Teaching a class			

Abbreviation: ICF, International Classification of Functioning, Disability, and Health.

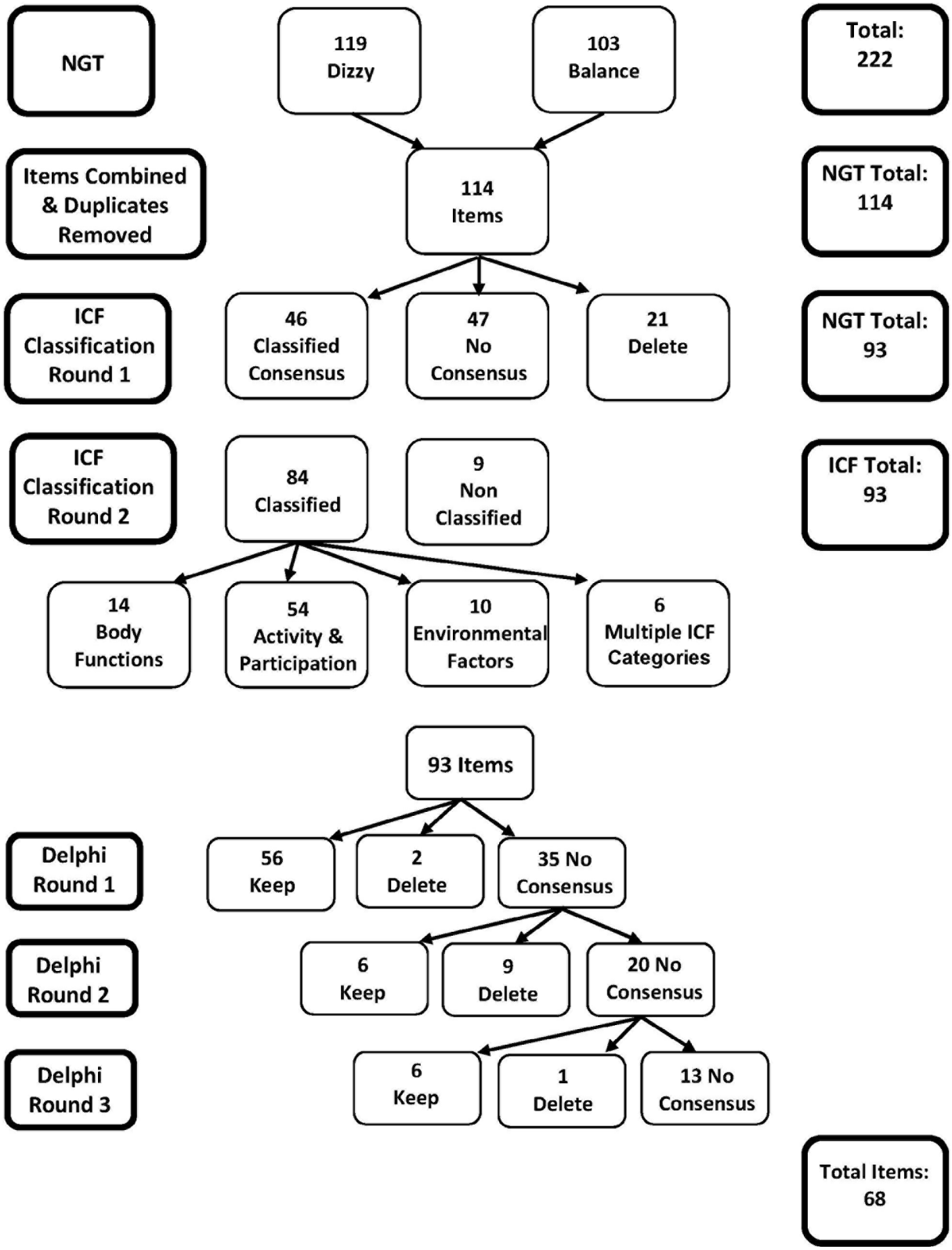

Figure 2 Model of item analysis.
Abbreviations: ICF, International Classification of Functioning, Disability, and Health; NGT, nominal group technique.

activities. The MCRI-DB includes more ambitious activities that are not included in the DHI. The MCRI-DB could potentially be used similarly to the DHI to recognize if the dizziness is caused by a functional, emotional, or physical problem. Unlike the DHI, the MCRI-DB might also help to determine return-to-duty ability for service members. Items on the DHI have been linked to the ICF.[24] Twenty-nine items were linked to activities and participation concepts and nine items to body functions, but no items were linked to environmental factors or body structures concepts. This again reveals that the DHI is more limited than the MCRI-DB in the concepts included from the ICF.

The SF-36 is a global health measure that is used as a subjective questionnaire in light of not having a military-specific tool. This tool does include some specific tasks that include light, moderate, and vigorous activities. The SF-36, however, does not explicitly address dizziness or imbalance, while the MCRI-DB includes specific tasks that cause dizziness or imbalance in service members who have blast-induced TBI. The military community has a different skill set from the civilian population. The MCRI-DB targets the specific skill sets of the military that the DHI, ABC, and SF-36 do not focus on.

Using service members in the NGT to develop the MCRI-DB aided in identifying actual tasks that service members who have dizziness or imbalance due to blast-induced mTBI have trouble performing, making this instrument suitable for service members who have been exposed to blasts. The strength of using the NGT is that the people who are affected guide this method. The use of experts to create the instrument might not have produced items that affect a service members' dizziness or balance. Use of a focus group may not be as practical as the NGT to produce the items on the questionnaire since a focus group does not promote full participation and one person may dominate the group.

Content validity was established by the use of the Delphi technique in the development of the MCRI-DB. Who better than the experts who treat this population understand the typical impairments a service member has after a blast-induced mTBI? These experts know what is missing in the instruments they use for service members who have dizziness or imbalance due to blast-induced mTBI. The use of this method helped to limit the responses that were produced from the NGT.

A vestibular subscale of environmental items from the ICF has recently been reported.[38] Six of the eight environmental items that Whitney et al reported (n=380 people from four countries) were also included in the MCRI-DB. The additional two items not included in the MCRI-DB were food and opinions/attitudes of others. It appears that the MCRI-DB captured many of the critical constructs related to environmental factors in the new measure.

When evaluating and treating service members, therapists are encouraged to consider all concepts of the ICF according to Weightman et al.[7] The items in this instrument were linked to the ICF where applicable. Even though the ICF does not precisely reflect military tasks, it is essential that instruments contain items that measure all aspects of military duty to include body functions, activities and participation, and environmental factors. The ICF linking will also improve the generalizability of the MCRI-DB in its measurement of change in a military population.

There were several limitations noted in this study. One such limitation is that the Delphi survey was sent as an electronic file for the experts to rate each of the 93 items on the four-point scale. The experts were asked to include any comments during each round. However, there was no place on the survey for the experts to comment after the items. The experts would have had to send their response in a separate email. No comments were generated.

Another limitation was that the members of the nominal group were recruited at Fort Bliss and WSMR. These are two Army posts. Consequently, other difficult tasks specific to other military jobs may not have been included in the MCRI-DB, which may limit its use with other branches of the military.

Finally, generalization of this questionnaire may also be limited due to the fact that only male Army service members participated in this study. Women were not intentionally omitted from this study; in fact, none qualified for recruitment. However, this tool may be applicable for female service members performing the same jobs as men in the military.

Although the MCRI-DB has not yet been tested on service members with dizziness or imbalance due to a concussion, with further development, it will potentially be a valuable clinical tool for this population. The plans for development include performing a beta test of the MCRI-DB on service members post-mTBI and comparing with outcomes that are commonly used in physical therapy setting for the military. For example, the MCRI-DB could be completed before and after receiving physical therapy and compared with the results obtained by outcomes such as the Rivermead Postconcussion Questionnaire, DHI, head impulse testing, dynamic visual acuity, Dix–Hallpike, computerized sensory organization test, Functional Gait Assessment, dual-task performance, and activity intolerance. Future studies should continue to

develop the MCRI-DB to determine its reliability and validity. Sixty-eight items are possibly too many to contain in a self-report questionnaire. Consequently, the first step may be to perform a factor analysis, which could determine which items should be included to fully capture the effect of mTBI on dizziness and balance problems in service members.[28] Once the final items are established, the MCRI-DB should be administered to service members experiencing mTBI to determine the feasibility, internal consistency, and test--retest reliability. The MCRI-DB should also be performed for all of the branches of service to assess the generalizability of the instrument.

Conclusion

With over 370,000 service members who have received a TBI since 2000, evaluation and management of these service members have been the priority of the DoD. According to DVBIC, TBI is a significant health concern for service members and veterans.[39] We know that service members have an increased possibility for a TBI compared with civilians regardless of war or peace.[39] There is a need to develop tools for assessment of this population.

A mixture of the use of service members' experiences in addition to expert opinion established the content validity of the MCRI-DB. The development of the MCRI-DB as a questionnaire that may be utilized as part of the evaluation of service members, who have faced mTBI, can assist with identifying functional activities, environmental factors, and body functions that may reduce these service members from safely and efficiently performing their military duties. The MCRI-DB may be useful as a tool to determine return-to-duty ability. Further research on the psychometric properties of the MCRI-DB is required to establish reliability and validity of this questionnaire.

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Author contributions

All authors contributed to data analysis, drafting and revising the article, gave final approval of the version to be published, and agree to be accountable for all aspects of the work.

Disclosure

The authors report no conflicts of interest in this work.

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Supplementary material

Table S1 Military Concussion Readiness Inventory for Dizziness and Balance (MCRI-DB)

Please answer each question as it relates to your dizziness or balance problems. Check "always," OR "sometimes," OR "never" to each question.					
Performing or being exposed to … increases my problems with dizziness or balance.					
1	… Abrupt movement	Always	Sometimes	Never	A&P
2	… Adrenaline rushes, stress	Always	Sometimes	Never	A&P
3	… Bending/reaching beyond neutral	Always	Sometimes	Never	A&P
4	… Carrying heavy objects	Always	Sometimes	Never	A&P
5	… Clearing houses	Always	Sometimes	Never	A&P
6	… Clearing obstacles	Always	Sometimes	Never	A&P
7	… Climbing	Always	Sometimes	Never	A&P
8	… Combat load/wearing gear	Always	Sometimes	Never	A&P
9	… Dismounting vehicles in gear	Always	Sometimes	Never	A&P
10	… Drill and ceremony (D & C)	Always	Sometimes	Never	A&P
11	… Driving	Always	Sometimes	Never	A&P
12	… Driving during the night	Always	Sometimes	Never	A&P
13	… Facing backwards while flying	Always	Sometimes	Never	A&P
14	… Firing large caliber weapons/missile firing	Always	Sometimes	Never	A&P
15	… Getting in/out of bed	Always	Sometimes	Never	A&P
16	… Getting up (bed, chair, toilet)	Always	Sometimes	Never	A&P
17	… Jumping (trampoline)	Always	Sometimes	Never	A&P
18	… Maintaining equipment/vehicles	Always	Sometimes	Never	A&P
19	… Mental exertion	Always	Sometimes	Never	A&P
20	… Navigating on rough terrain	Always	Sometimes	Never	A&P
21	… Obstacle course	Always	Sometimes	Never	A&P
22	… Picking things off the ground	Always	Sometimes	Never	A&P
23	… Riding in back of vehicles	Always	Sometimes	Never	A&P
24	… Riding in military vehicle/enclosed vehicles	Always	Sometimes	Never	A&P
25	… Ruck marching	Always	Sometimes	Never	A&P
26	… Running	Always	Sometimes	Never	A&P
27	… Sports: basketball/volleyball/football	Always	Sometimes	Never	A&P
28	… Sports: surfing/snow/wake/skate boarding	Always	Sometimes	Never	A&P
29	… Sprinting with quick stops	Always	Sometimes	Never	A&P
30	… Standing in formation	Always	Sometimes	Never	A&P
31	… Traveling (trains/planes/auto/bus/boat)	Always	Sometimes	Never	A&P
32	… Uneven surfaces	Always	Sometimes	Never	A&P
33	… Walking a straight line	Always	Sometimes	Never	A&P
34	… Walking down/up stairs	Always	Sometimes	Never	A&P
34	… Walking down/up stairs	Always	Sometimes	Never	A&P
35	… Walking in crowds	Always	Sometimes	Never	A&P
36	… Walking/hiking narrow paths	Always	Sometimes	Never	A&P
37	… Wearing an advanced combat helmet (ACH)	Always	Sometimes	Never	A&P
38	… Anxiety, worry, fear	Always	Sometimes	Never	BF
39	… Dehydration	Always	Sometimes	Never	BF
40	… Migraines/headaches	Always	Sometimes	Never	BF
41	… Nuclear Biological Chemical (NBC) mask	Always	Sometimes	Never	BF
42	… Over exerting/physical exertion/excessive physical activity	Always	Sometimes	Never	BF
43	… Sleep deprivation: waking up at early hours/working long hours >24 hours	Always	Sometimes	Never	BF
44	… Strain/bearing down	Always	Sometimes	Never	BF
45	… Tinnitus/inner ear disturbance	Always	Sometimes	Never	BF
46	… Alcohol/drugs/medication	Always	Sometimes	Never	EF
47	… Altitude/elevation	Always	Sometimes	Never	EF
48	… Busy vision (transitioning through a change in light, looking at busy background)	Always	Sometimes	Never	EF
49	… Confined areas (rooms/vehicles)	Always	Sometimes	Never	EF
50	… Excessive light	Always	Sometimes	Never	EF

(*Continued*)

Table S1 Military Concussion Readiness Inventory for Dizziness and Balance (MCRI-DB)

Please answer each question as it relates to your dizziness or balance problems. Check "always," OR "sometimes," OR "never" to each question.					
Performing or being exposed to … increases my problems with dizziness or balance.					
51	… Flash bangs (bright light and loud noises)	Always	Sometimes	Never	EF
52	… Flashing lights	Always	Sometimes	Never	EF
53	… Heat	Always	Sometimes	Never	EF
54	… Sound	Always	Sometimes	Never	EF
55	… Staring at TV/computer	Always	Sometimes	Never	EF
56	… Food/caffeine (too much/too little)	Always	Sometimes	Never	Multi
57	… Land navigation	Always	Sometimes	Never	Multi
58	… Playing video games	Always	Sometimes	Never	Multi
59	… Reading	Always	Sometimes	Never	Multi
60	… Rifle marksmanship/shooting a weapon	Always	Sometimes	Never	Multi
61	… Heights	Always	Sometimes	Never	None
62	… Looking up	Always	Sometimes	Never	None
63	… Mounted gun turrets	Always	Sometimes	Never	None
64	… Moving the head with eyes closed	Always	Sometimes	Never	None
65	… Multiple transition colors	Always	Sometimes	Never	None
66	… Night vision goggles (NVG)	Always	Sometimes	Never	None
67	… Turning around	Always	Sometimes	Never	None
68	… Using gym equipment	Always	Sometimes	Never	None
How many					
		×4	×2	×0	
Total					

Abbreviations: A&P, activity and participation; BF, body functions; EF, environmental functions; Multi, multiple ICF categories; None, unable to be coded to a specific ICF category.