

Functional Screening for Vestibular and Balance Problems Soon After Head Injury: Options in Development for the Field or Aid Station

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ABSTRACT

Vestibular balance dysfunction has been documented as a military problem after duty-related barotrauma and/or traumatic head acceleration. We are fostering the development of rapid, portable, fieldable tests of balance function after such vestibular insults. We consulted on military-relevant tests with more than 50 vestibular researchers, scientific advisors, clinicians, and biomedical engineers working for government agencies, universities, clinics, hospitals, or businesses. Screening tests and devices appropriate for early (post-injury) military functional assessment were considered. Based on these consultations, we recommend that military field tests emphasize dynamic, functional, and duty-relevant aspects of standing balance, gait, visual acuity, perception of visual vertical, and vertigo. While many current tests are useful for the clinic, they often require modification before they are suitable for military field and aid station settings. This report summarizes likely future military testing needs, giving priority to testing approaches in development that promise to be rapid, portable, field-ready, semiautomated, usable by a nonspecialist, and suitable during testing and rehabilitation.

The Need for Vestibular/Balance Tests Suitable for Early Testing After Injury

Head injury is a major concern of military medicine due to exposure of personnel to explosive blasts, vehicle collisions/rollovers, falling, or other sources of duty-related head injury.¹ As with other combat personnel, Special Operations personnel have been injured by blast² and vehicle accidents.³ Sufferers of concussion or mild traumatic brain injury (mTBI) commonly report symptoms such as dizziness and (often migrainous) headache.⁴ Because the vestibulocochlear organs and central vestibular systems are highly sensitive to pressure and head acceleration, it is no surprise that the majority of patients with mTBI in the military setting show evidence of

vestibular pathology and balance problems.^{5,6} Vestibular pathologic conditions have been documented extensively after concussion, mTBI, and barotraumas and are known to be associated strongly with dizziness, vertigo, and disequilibrium.⁷⁻⁹

Dizziness has been described as a nonspecific sense of disorientation, whereas vertigo has been characterized as an illusion of self-motion.¹⁰ The patient will use the terms interchangeably, but the clinician can distinguish them through careful questioning and evaluation.^{6,11,12} Dizziness and vertigo are disturbing symptoms that may prompt patients to go to the emergency department. Nearly 70% of emergency department patients reporting dizziness/vertigo as their chief complaints are diagnosed with a vestibular problem.¹³ Dizziness/vertigo may persist for many months after head injury, and these symptoms contribute disproportionately to a person's degraded performance or disability after head injury.^{4,10,11,14} We expect that few Soldiers will feel able to perform when they are experiencing episodes of vertigo that prevent them from confidently standing or walking, whereas many other common signs and symptoms of mild blast injury (e.g., headache, tinnitus, partial hearing loss) might be tolerated more readily under most circumstances. Disruption of balance diminishes Soldier readiness (or fitness-for-duty), resulting in prolonged inability to return to regular duty and increasing the risk of further injury (e.g., by contributing to falling or vehicle accidents).¹⁵ Hoffer, Gottshall, and Balough⁶ estimate that untreated balance disorders cost the U.S. military more than \$500 million per year in lost equipment and unsuccessful mission accomplishment, resulting in the medical discharge of valuable personnel, and ultimately costing billions of dollars per year in retraining and medical benefits.

Recently, a number of authors and agencies have noted the need for better functional screening tools after mTBI¹⁶⁻¹⁸ and, in particular, for improved vestibular evaluation after

exposure to improvised explosive devices (IEDs).^{8,9,19,20} Military medics, corpsmen, and aidmen require easy-to-use tools that allow rapid and early post-injury testing to assist with decisions concerning whether a Soldier should return to duty or be referred for further evaluation. Tests providing automated administration and scoring will yield better consistency than is common with many subjective tests used presently (e.g., the Military Acute Concussion Evaluation).¹⁸ Technologies are being developed for evaluation of mTBI, but few focus on vestibular and balance functioning. This gap in focus seems inadvisable, because nearly all military missions require good balance and gaze control. Another potential problem with current systems used to assess mTBI effects is that they generally are developed separately from systems for mTBI rehabilitation. It may be advantageous if a combination system was developed with assessment and rehabilitation capabilities integrated into a single unit (or a closely coordinated suite of tests) composed of consistent, well-designed procedures and interfaces. This would decrease total equipment footprint and decrease the number of devices that need to be procured, learned, and maintained. We met with experts to identify a strategy to fill some of these gaps.

Expert Consultations on Military Vestibular/Balance Testing

This report represents our thoughts based on discussions with approximately 54 distinct persons (some people were consulted more than once) with expertise in human balance and vestibular function. The people consulted included experienced researchers, scientific advisors, otolaryngologists (ear, nose, and throat specialists), physical therapists, audiologists, and biomedical engineers. Our consultations included people in academia, industry, and/or the government (e.g., Department of Defense, National Institutes of Health, National Aeronautics and Space Administration).

Our group considered military-appropriate balance tests for early assessment after injury.^{9,20,21} We provided advice concerning the optimal design and implementation of tests and protocols intended to enhance future balance assessment and recovery in the military setting. The “group” we refer to throughout this report is defined as the 54 people who attended one or more of four meetings we held, as follows: (meetings 1 and 2) two preliminary meetings in Pensacola, FL, the first of which²¹ was attended by six people and the second by 13; (meeting 3) an invitational workshop in Rockville, MD, attended by 16 people;²⁰ and (meeting 4) consultations in Europe with a total of 30 professionals attending two international vestibular conferences in Reykholt and Reykjavik, Iceland.²⁰ These meetings and the participants are described further in a 102-page government technical

report.²⁰ The essential findings are summarized for the first time in a journal here.

Features of an Optimal Test

Our group started by summarizing the features that an ideal future military field test would possess. The ideal test should be sensitive, reliable, specific, designed for initial functional screening (rather than diagnosis) to determine if further care and diagnostic testing are needed, user-friendly (e.g., usable by a medic after one hour of training), rapidly administered and interpreted, portable (i.e., small and light), rugged (i.e., having reliable hardware) and stable (i.e., proved software), militarily relevant (e.g., clear face validity to aid return-to-duty decisions), clinically relevant (e.g., relevant to procedures and standards of clinical practice), semiautomated, multifunctional (e.g., performs testing and rehabilitation), accepted by users (e.g., comfortable, noninvasive), and mature (e.g., test properties known and system ready for use).

The Three Major Categories of Functional Ability That Should be Evaluated

The group decided that the emphasis of their recommendations would be on simple functional tests and less on sophisticated, comprehensive, or less portable test devices, such as commercially available rotatory visual-vestibular tests or higher-end computerized dynamic posturography systems. Nevertheless, such tests serve as important standards for comparison as new field tests are developed. Several functional abilities are critical to service members and are degraded by vestibular aspects of head injury. We categorized three main functional abilities, along with citations of one or more reference tests in each category of ability. These categories are (1) head-gaze coordination to maintain good visual processing with reference tests by dynamic visual acuity, head thrust, and various commercially available visual-vestibular rotatory testing systems;^{12,22-24} (2) maintenance of accurate spatial orientation perception with reference tests by subjective visual vertical estimates during conditions of head tilt or off-center rotation²⁵⁻²⁷; and (3) balance functioning to maintain coordination during standing and locomotion with a reference test for standing balance by computerized dynamic posturography, especially under conditions of diminished visual and somatosensory cueing.^{7,28,29} No gold standard exists yet for a gait test in young military blast/concussion patients, but some of the main options²⁸⁻³⁴ are discussed next.

A Subset of Screening Tests Suitable for Possible Integration Into a Future Portable Battery

The authors generated an initial list of 17 possible tests for consideration in future functional screening in the

field setting, the battalion aid station, or a full care center (Figure 1).²⁰ They considered which of the full list of potential tests were most suitable for integration into a single suite of tests for functional screening in the military. They envisioned a portable battery of tests that would be supported for accelerated development and delivery. The battery should include aspects of each of the three categories of function (e.g., head-gaze, balance, orientation), should meet the key requirements identified (e.g., validated, portable, medic-friendly, allow laptop-based administration, and provide test results), and should be capable of integration with one another into a single system or a compatible suite. Each test could be made commercially available in three years or less, although full military validation and procurement would add many years to that estimate. The portable subjective visual vertical and portable posturography tests are current areas of focus for the authors and their colleagues. Head-gaze coordination could be assessed by an automated dynamic visual acuity test performed at a battalion aid station.²² Spatial orientation perception could be assessed by measuring the subjective visual vertical via automated goggles deployable in the field²⁷ (Figure 2) and a Dizziness Handicap Inventory (DHI) that could be used anywhere, but would benefit from modification to improve military applicability.²⁸ The functional balance test would involve a portable (e.g., suitcase-size) posturography device during additional stressors (e.g., cognitive tasking, external perturbation of sway, addition of head movement, pretest exertion) that could be used at the battalion aid station^{29,31,32,35} and a functional gait assessment (FGA) that could be used in the field, but would benefit from modification to improve military applicability.^{32,34}

Further Details on Functional Balance Tasks Suitable for Sway Testing

Using the expert recommendations as a point of departure, the authors devised a list of desired testing capabilities from functional balance that could be readily incorporated into near-future generations of multisensory balance testing and cueing (and rehabilitation) devices.^{36,37} The authors gave special consideration to tests that also could serve as treatments by using the same basic hardware, but having different user interfaces and protocols for testing versus treatment. The fundamental device capabilities listed next are deemed worthy of consideration for testing and treatment (e.g., vestibular rehabilitation) at a single portable clinical workstation that could be located as far forward as a battalion aid station. Some of these capabilities are emerging from our team's ongoing small business innovative research efforts, although much development, automation, and refinement remain to be done. The item that we list that is most likely to be ready in the near-term is head movements



Figure 1 *The military needs vestibular/balance tests that can be administered in the field (top left) or at the battalion aid station (right), not just in full care centers (bottom).*

during balance performance, which is a current area of focus for the authors.

The full list is as follows:

1. Balance performance: With or without visual, auditory, and/or tactile cueing.
 - a. Using different stances.
 - b. During paced head movements with or without simultaneous attempts to control gaze or read a display.²²
 - c. While cognitively tasked.³⁵
 - d. After external mechanical perturbation (e.g., unpredictable, measured push).
2. Related functional activities: With or without visual, auditory, and/or tactile cueing.
 - a. One-legged standing.
 - b. Lunging.
 - c. Partial proxies of gait (e.g., heel-to-toe walking, stepping).
 - d. Squatting, moving from sitting to standing.³⁷
 - e. Simulated dynamic weapon skills.³²

Thoughts Concerning a Logical Sequence of Testing

Our group considered the logical sequence of testing following a mild head injury in the military setting. Our focus was on tests for the field or aid station, not just the full care center (Figure 1). The following suggested sequence of tests (some of which are still in development) would be ideal for a future battery. First, primary field testing would be performed by a medic post-injury, starting with the subjective visual vertical (SVV) and then the FGA (all subtests not requiring head movement). The SVV is one of the key exams a specialist can do without a full-up rotation device to see if the patient



Figure 2 An example of a simple field test for vestibular function developed recently by Dr. Andrew Clarke and colleagues of the Charité Medical School of Berlin and being evaluated by the authors of this report. This is a portable, automated version of the subjective visual vertical test, which detects unilateral otolith dysfunction (unilateral deficit can cause inability to orient a line vertically).

has a vestibular problem. It involves asking the patient to set a line of light to the perceived earth-vertical in darkness. Healthy people do this very accurately, but people injured on one side (e.g., with a bad unilateral vestibular otolith problem) cannot. This is a fast test to do and some evidence suggests this method is more sensitive to certain types of pathology than reflexive otolith measures such as ocular torsion. Such testing would commence as soon as possible after mTBI. The total time should be approximately 10 minutes. Tests should be transportable in a small tote bag and administered anywhere with a level surface. If scores are abnormal, the patient would proceed to the battalion aid station. It should be possible to proceed with FGA subtests requiring head movement if the patient shows no signs of neck injury and can easily move his or her head around voluntarily (e.g., good cervical range of motion). If there is any doubt, head movement tests can be deferred for secondary testing.

Next, secondary testing would be done at a battalion aid station wherein medical personnel would check neck movement further if needed, then perform static posturography, followed by a dynamic visual acuity test. The total time should be approximately 30 minutes. All test devices should be transportable in the rear seat of a vehicle and administered anywhere there is a level surface and not too much noise. If scores are abnormal, then the patient could be referred to a specialist if needed for further diagnosis.

Finally, tertiary testing and care would be handled by specialists (e.g., otolaryngologist) at a comprehensive care center with the standard set of tests, including cervical/ocular vestibular-evoked myogenic potential (VEMP),

computerized dynamic posturography, and full clinical rotator chair testing.^{7,23,38}

Conclusions

Our recommendations are not intended as comprehensive diagnostic guidelines or testing standards (e.g., we do not discuss simple bedside tests of spontaneous nystagmus), but rather to draw attention to tests requiring further development to permit the earliest possible functional screening after injury in the military setting (e.g., to aid a medic's decision concerning whether the patient requires further diagnostic testing by a physician). For initial testing in the field by a medic, we recommend development of a portable device that permits rapid testing and interpretation of orientation perception and gaze/balance functioning. Several aspects of such an automated system are in development by the authors and others, but some aspects have not been fully automated yet, nor integrated with established military medical records systems, nor bundled into one suite of capabilities. We predict that some of the orientation and balance testing capabilities under development may become available commercially as early as 2015. Full validation of any test requires much longer.

It may become possible in the future to commence initial therapy at the aid station using the same portable device employed for testing, provided the device is designed for both testing and rehabilitation applications and therapy is warranted for a diagnosed balance problem. Usually, such treatment includes vestibular rehabilitation and other appropriate physical therapy, but patient and device availability in the field may be constrained by operational requirements, so treatment must be flexible and

the device should be as automated and patient-controlled as possible.

Eventually, cervical/ocular VEMP tests³⁸ (which we currently list for full care centers) could be incorporated at the battalion aid station level. The ocular VEMP is rapidly administered and well tolerated and requires no special tasks on the part of the patient. Presently, VEMP tests are available only at some full care centers and require expertise to interpret, so further development is needed.

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Disclaimer

The views we have expressed in this report do not represent the views of the U.S. Government or its subordinate agencies. Our mention of agencies or persons in this report does not imply their endorsement. Any mention of commercial products is not meant to imply endorsement of those products.

References

1. Office of the Surgeon General, U.S. Army Medical Department. (17 May 2007). Report to the Surgeon General Traumatic Brain Injury Task Force report. Retrieved 10 February 2011 from Army Medicine website. Website: (www.armymedicine.army.mil/reports/tbi/TBITaskForceReportJanuary2008.pdf).
2. Brooks D. (7 March 2012). Brain-injured Soldiers urged to seek treatment. *Fayetteville Observer*. Retrieved 15 May 2012 from Fayetteville Observer website. Website: (<http://fayobserver.com/articles/2012/03/07/1162195?sac=fo.military>).
3. Hettich T, Whitfield E, Kratz K, Frament C. (2010). Case report: use of the immediate post concussion assessment and cognitive testing (ImPACT) to assist with return to duty determination of Special Operations Soldiers who sustained mild traumatic brain injury. *Journal of Special Operations Medicine*. 10(4):48–55.
4. Terrio H, Brenner LA, Ivins BJ, Cho JM, Schwab K, Scally K, Bretthauer R, Warden D. (2009). Traumatic brain injury screening: preliminary findings in a U.S. Army brigade combat team. *Journal of Head Trauma Rehabilitation*. 24(1):14–23.
5. Balaban C, Hoffer ME. (2009). Mild traumatic brain injury: Vestibular consequences [Presentation]. *Defense Center of Excellence Global VTC, Brain Injury Awareness* Retrieved 18 March 2010 from Defense Centers of Excellence website. Website: (www.dcoe.health.mil/Training/GlobalVTCs.aspx).
6. Hoffer ME, Gottshall KR, Balough BJ. (13 January 2009). Evaluation and management of dizziness after head trauma [Presentation]. *U.S. Naval Aeromedical Conference*. Naval Air Station, Pensacola, FL.
7. Nashner LM. (1997). Computerized dynamic posturography: clinical applications. In: GP Jacobson, CW Newman, JM Kartush, Eds. *Handbook of Balance Function Testing*. New York: Thompson. pp. 308–334.
8. Scherer MR, Schubert MC. (2009). Traumatic brain injury and vestibular pathology as a comorbidity after blast exposure. *Physical Therapy*. 89:980–992.
9. Lawson BD, Rupert AH. (2010). Vestibular aspects of head injury and recommendations for evaluation and rehabilitation following exposure to severe changes in head velocity or ambient pressure. In: O Turan, J Bos, J Stark, J Colwell, Eds. *Proceedings of the International Conference on Human Performance at Sea (HPAS)*. Glasgow, U.K. pp. 367–380.
10. Luxon LM. (1996). Posttraumatic vertigo. In: RW Baloh, GM Halmagyi, Eds. *Disorders of the Vestibular System*. New York: Oxford University Press. pp. 381–395.
11. Fausti AS, Wilmington DJ, Gallun FJ, Myers PJ, Henry AJ. (2009). Auditory and vestibular dysfunction associated with blast related traumatic brain injury. *Journal of Rehabilitation Research and Development*. 46(6):797–810.
12. Herdman SJ, Ed. (2007). *Vestibular Rehabilitation*. 3rd ed. Philadelphia: F.A. Davis.
13. Ciupe A, Margraf A, Zwergal A, Brandt T, Jahn K. (June 2012). Vestibular syndromes in emergency medicine: a retrospective analysis. *Abstracts from the 27th Bárány Society Meeting*, Uppsala, Sweden. Retrieved from the Bárány Abstracts website. Website: (<http://www.barany2012.se/Pdf/Barany-abstracts-web.pdf>).
14. Mueller M, Strobl R, Doring A, Grill A. (June 2012). Burden of disability attributable to vertigo in the aged: results from the KORA-age study. *Abstracts from the 27th Bárány Society Meeting*, Uppsala, Sweden. Retrieved from the Bárány Abstracts website. Website: (<http://www.barany2012.se/Pdf/Barany-abstracts-web.pdf>).
15. Sylvia FR, Drake AI, Wester DC. (2001). Transient vestibular balance dysfunction after primary blast injury. *Military Medicine*. 166:918–920.
16. Tanner B. (June 2007). Traumatic Brain Injury: An operational update. Presented at the *United States Marine Corps Combat/Operational Stress Control Conference*: Arlington, VA.
17. Megna J. (2007). Balance and vestibular rehabilitation in the patient with acquired brain injury. In: J Elbaum, DM Benson, Eds. *Acquired Brain Injury: An Integrative*

Neuro-rehabilitation Approach. New York: Springer, pp. 200–214.

18. French L, McCrea M, Baggett M. (2008). The military acute concussion evaluation (MACE). *Journal of Special Operations Medicine*. 8(1)(Winter):68–77.
19. Myers PJ, Wilmington DJ, Gallun FJ, Henry JA, Fausti SA. (2009). Hearing impairment and traumatic brain injury among soldiers: Special considerations for the audiologist. *Seminars in Hearing*. 30:5–27.
20. Lawson BD, Rupert AH, Legan SM. (2012). Vestibular and balance deficits following head injury: recommendations concerning evaluation and rehabilitation in the military setting. Fort Rucker, AL: United States Army Aeromedical Research Laboratory. USAARL Report No. 2012-10.
21. Rupert AH, Lawson BD. (2011). Initial consideration of the feasibility and optimal application of tactile sway cueing to improve balance among persons suffering from disequilibrium. Fort Rucker, AL: U.S. Army Aeromedical Research Laboratory. USAARL Report 2011-01.
22. Gottshall K, Drake A, Gray N, McDonald E, Hoffer ME. (2003). Objective vestibular tests as outcome measures in head injury patients. *Laryngoscope*. 113:1746–1750.
23. McKinnon B, Kiderman A, Ives TE. (2008). A case study: neuro-otologic test center evaluation in mild traumatic brain injury. Neuro Kinetics, Inc. Pittsburgh, PA. Retrieved from the Neuro Kinetics website. Website: (www.neurokinetics.com/docs/mild-traumatic-brain-injury.pdf).
24. Goebel J, Tungscript N, Sinks B, Carmody J. (2007). Gaze stabilization test: a new clinical test of unilateral vestibular dysfunction. *Otology and Neurotology*. 28:68–73.
25. Friedmann G. (1970). The judgment of the visual vertical and horizontal with peripheral and central vestibular lesions. *Brain*. 93:313–328.
26. Clarke AH, Schönfeld U, Hamann C, Sherer H. (2001). Measuring unilateral otolith function via the otolith-ocular response and the subjective visual vertical. *Acta Otolaryngologica Supplementum*. 545:84–87.
27. Schönfeld U, Clarke AH. (2011). A clinical study of the subjective visual vertical during unilateral centrifugation and static tilt. *Acta Otolaryngologica*. 131(10):1040–1050.
28. Jacobson GP, Newman CW. (1990). The development of the dizziness handicap inventory. *Archives of Otolaryngology-Head and Neck Surgery*. 116:424–427.
29. Rupert AH, Lawson BD, McGrath EF, Wood SJ. (2011). Computerized posturography incorporating static and dynamic head tilts [Abstract]. *Journal of Vestibular Research*; 21(2):74.
30. Jain V, Wood SJ, Feiveson AH, Black FO, Paloski WH. (2010). Diagnostic accuracy of dynamic posturography testing after short-duration space flight. *Aviation, Space, and Environmental Medicine*. 81:625–663.
31. Rine R, Roberts D, Corbin BA, McKean-Cowdin R, Varma R, Beaumont J, Slotkin J, Schubert MC. (2012). A new portable tool to screen vestibular and visual function in children and adults — National Institutes of Health Toolbox initiative [Abstract]. *Journal of Rehabilitation Research & Development*. 49(2):209–220.
32. Webb CM, Lawson BD, King MR, Cruz PA, Kelley AM, Erickson BS. (2012). Development of a fitness-for-duty assessment battery for recovering dismounted warriors: Phase 1. Abstract submitted to the Military Health System Research Symposium, August 2012.
33. Cohen HS, Sangi-Haghpeykar H. (2011). Walking speed and vestibular disorders in a path integration task. *Gait and Posture*. 33(2):211–213.
34. Wrisley DM, Marchetti GF, Kuharsky DK, Whitney SL. (2004). Reliability, internal consistency, and validity of data obtained with the functional gait assessment. *Physical Therapy*. 84(10):906–918.
35. Shumway-Cook A, Woollacott M, Kerns K, Baldwin M. (1997). The effects of two types of cognitive tasks on postural stability in older adults with and without a history of falls. *The Journals of Gerontology Series A, Biological Sciences and Medical Sciences*. 52A:M, 232–240.
36. Mortimer B, Dutta A. (2010). Sensory augmentation in a complex balance task. *Proceedings of the Telluride Neuromorphic Cognition Engineering Workshop*, Telluride, CO. Retrieved 17 July 2011 from the Neuromorphics website. Website: (<https://neuromorphs.net/nm/attachment/wiki/2010/bmi10/uni/Sensory%20Augmentation%20in%20a%20Complex%20Balance%20Task%202.pdf>).
37. Atkins K. (2010). Vibrotactile postural control in patients that have sit-to-stand balance deficit and fall. Fort Rucker, AL: U.S. Army Aeromedical Research Laboratory. USAARL Report No. 2010-18.
38. Curthoys IS, Manzari L, Smulders YE, Burgess AM. (2009). A review of the scientific basis and practical application of a new test of utricular function—ocular vestibular-evoked myogenic potentials to bone-conducted vibration. *Acta Otorhinolaryngologica Italica*. 29(4):179–186.

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