Chapter 3

BALANCE AND FUNCTIONAL ABILITIES ASSESSMENT AND INTERVENTION

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INTRODUCTION

SECTION 1: BALANCE ASSESSMENT
    Introduction
    Activities-Specific Balance Confidence Scale
    Single-Limb Stance Test
    Romberg and Sharpened Romberg
    Balance Error Scoring System
    Modified Clinical Test of Sensory Integration and Balance
    Balance Evaluation Systems Test
    Mini-Balance Evaluation Systems Test of Dynamic Balance
    Computerized Dynamic Posturography
    High-Level Mobility Assessment Tool
    Revised High-Level Mobility Assessment Tool
    Gait Speed
    Functional Gait Assessment
    Illinois Agility Test
    Five Times Sit-To-Stand Test

SECTION 2: BALANCE INTERVENTION
    Higher-Level Balance and Functional Abilities: Therapist Points to Remember
    Fitness and Conditioning Program for Balance Retraining Following
      Vestibular Dysfunction

REFERENCES

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INTRODUCTION

Balance deficits that arise in conjunction with concussion/mild traumatic brain injury (c/mTBI) typically occur as a result of vestibular dysfunction.[1,2] Residual balance deficits often follow treatment for a vestibular disorder, and treatment is individualized and specific to the cause. Several assessments[1,3–5] attempt to identify systems that may contribute to residual balance deficits.

The assessment section of this chapter includes evaluation of body structure/function, activity, and participation level of functioning. Therapists are encouraged to use a battery of assessments to clarify the causes and impacts of balance deficits on an individual service member, with the understanding that no currently available tool focuses on the impact of balance on military-related skills. The intervention section of this chapter provides a tip sheet of options and considerations for balance intervention.

Although assessing balance and functional abilities is considered a **practice standard**, the choice of which specific assessment tools to use is up to the individual therapist (**practice option**). Therapists are encouraged to measure both static and dynamic balance to fully characterize deficits in the complex military population. Measuring comfortable and fast gait speed, which has been considered by some to be a vital sign and correlates to levels of function in many areas, is the one method considered a practice standard.[6] Support for balance deficit treatment is based on evidence for specific populations, such as the elderly, but remains lacking specific to individuals in the age range and with the comorbidities of the typical military population. Support for vestibular rehabilitation programs to address residual balance deficits, especially following blast exposure, is expanding.[1] The intervention suggestions described here are considered practice options.

SECTION 1: BALANCE ASSESSMENT

INTRODUCTION

Because balance issues that result from c/mTBI are often related to vestibular deficits, a vestibular deficit screen is recommended, with more thorough testing recommended if findings suggest vestibular impairment.[1,2] Tests commonly used to assess balance in the elderly or in those with other medical disorders are often not sensitive to the high-level functional abilities of service members with c/mTBI and demonstrate a "ceiling effect" (ie, subjects score at the upper limit of an instrument's range, therefore actual variation in data is not reflected in scores).[7–10] Tests such as the High-Level Mobility Assessment Tool (HiMAT), the Functional Gait Assessment (FGA), and the Illinois Agility Test (IAT), in addition to the use of dynamic posturography where available, may provide the appropriate level of challenge for this population.[7–10] For those service members with complex deficits, the more time-intensive Balance Evaluation Systems Test (BESTest) may be considered to clarify the underlying systems contributing to the service member's deficits.[4] A mini-BESTest has been developed to measure the

single dimension of "dynamic balance."[11] Although both BESTest versions have been used primarily in older adults, they may be useful in a service member population. Therapists should consider military-relevant obstacle courses and activities, possibly using completion time as a measurement. However, there are no standardized balance assessments for that level of challenge at this time.

Therapists should be aware that many of the assessment tools included in this section have limited or no psychometric information on individuals of typical military age and with the customary fitness level required for military readiness. Data is provided for the younger population if available, although most information is found for middle-aged and older adults or those with specific neurological disorders. The choice of tools used to assess balance and functional deficits is up to the individual therapist. A range of psychometric information is provided to allow therapists to make informed decisions related to the needs of the individual service member.

ACTIVITIES-SPECIFIC BALANCE CONFIDENCE SCALE

Purpose/Description

The Activities-Specific Balance Confidence (ABC) Scale was developed as an evaluative measure to assess balance confidence in ambulatory community-dwelling older adults (Exhibit 3-1). Each activity requires position changes or walking in progressively more difficult situations. The ABC

EXHIBIT 3-1

ADDITIONAL RESOURCES FOR THE ACTIVITIES-SPECIFIC BALANCE CONFIDENCE SCALE

This instrument can be obtained from the original publication:

- Powell LE, Myers AM. The Activities-specific Balance Confidence (ABC) Scale. *J Gerontol Med Sci*. 1995;50 (1):M2834.

It can also be found at the following:

- Rehabilitation Institute of Chicago, Center for Rehabilitation Outcomes Research, Northwestern University Feinberg School of Medicine Department of Medical Social Sciences Informatics Group. Rehabilitation Measures Database. www.rehabmeasures.org/Lists/RehabMeasures/DispForm.aspx?ID=949&Source=http%3 A%2F%2Fwww%2Erehabmeasures%2Eorg%2Frehabweb%2Fallmeasures%2Easpx%3FPag eView%3DShared. Accessed July 8, 2013.
- University of Missouri, School of Health Professions, Department of Physical Therapy. Geriatric Examination Toolkit. web.missouri.edu/~proste/tool/vest/index.htm. Accessed July 8, 2013.
- Southampton Hospital website. www.southamptonhospital.org/Resources/10355/FileRepository/Forms/Dizziness%20 Hanicap%20Inventory%20-%20English.pdf. Accessed July 8, 2013.

Scale uses an 11-point scale, ranging from 0 (no confidence) to 11 (complete confidence).[12]

Recommended Instrument Use

The ABC Scale is a participation-level measure of balance. Situations are more related to home and community environment and may not be relevant to military activities; however, this self-test is typically used to assess the impact of balance deficits on daily functioning.

Administration Protocol/Equipment/Time

This is a paper-and-pencil self-test that takes about 5 minutes to administer and 5 minutes to score.

Groups Tested With This Measure

The ABC Scale has been used in community-dwelling elderly adults,[12] retirement home residents, and those undergoing hip and knee replacements[13]; in persons with vestibular disorders, including migraine-related vestibulopathy[14–16]; and in persons with stroke.[17]

Interpretability

- Norms: 100% corresponds to complete balance confidence. According to the developers, individuals who score above the mid-80s tend to be highly functioning and physically active.[13]
- Minimal detectable change (MDC): Information is not available on persons with concussion/mTBI. MDC based on a 95% confidence interval ($MDC_{95\%}$) = 21.7 in 60 community-dwelling seniors.[12] $MDC_{95\%}$ = 17.5 in 50 lower-extremity amputees in an outpatient setting.[18] If the patient's score is less than the MDC value, it is considered indistinguishable from measurement error.

Responsiveness Estimates

- Patients with vestibular diagnoses with migraine had a mean change of 12%, and those with vestibular diagnoses without history of migraine had a mean change of 25%.[19]
- A mean change of 10% was found in patients with moderate to severe loss of vestibular function following physical therapy intervention.[20]

- The ABC Scale was found not responsive to change (mean change – 1.1) in 213 noninstitutionalized women aged 70 and over, undergoing a 12-week, home-based, fall prevention program of exercise, education, and individualized risk-reduction counseling; however, the finding may have been related to a ceiling effect in high-functioning women.[21]

Reliability Estimates

- Internal consistency: Chronbach's alpha = 0.95[21]
- Interrater: not applicable, questionnaire
- Intrarater: not applicable, questionnaire
- Test-Retest: total ABC Scale scores r = 0.92 in community-dwelling elderly[12]; intraclass correlation (ICC) (3,1) = 0.91 in 50 outpatients with lower extremity amputation[18]

Validity Estimates

- Content/Face: Items for the ABC Scale were generated by 15 clinicians and 12 elderly outpatients using the Falls Efficacy Scale, with the addition of more situation-specific measures of balance confidence.[12]
- Criterion: correlation between ABC Scale and the Survey of Activities and Fear of Falling in older women: r = – 0.65[21]; correlation with Dizziness Handicap Inventory (DHI) in patients in a balance and vestibular clinic (ages 26–88), r = – 0.64.[15] In 167 patients with mild balance impairment, the odds ratio for frequent falling (adjusted for age and gender) was not significant (OR = 0.71).[22] The average ABC Scale score for persons who fall was 38% and for nonfallers was 81%.[12] In 287 persons (270 females, 17 males) in senior living facilities, persons with ABC Scale scores less than 50% were 2.6 times more likely to be depressed, 3.8 times more likely to walk slower than 0.9 m/s, 4.4 times more likely to use an assistive device for walking, and 5.4 times more likely to have impaired gait and balance than persons with ABC Scale scores over 50%.[23]
- Construct: ABC Scale correlated with tandem stance time (r = 0.59), with single-leg stance time (r = 0.59), with tandem walking (r = – 0.52), with the 6-minute walk test (r = 0.63), and with Tinetti's Performance Oriented Mobility Assessment (r = 0.64) in 1,767 mildly balance-impaired older adults involved in a balance-training and fall-reduction program (Form 3-1).[22]

Administration

The ABC Scale can be self-administered or conducted via personal or telephone interview. Larger font size should be used for self-administration testing, while an enlarged version of the rating scale on an index card will facilitate interviews. Each respondent should be queried concerning their understanding of the instructions, and probed regarding difficulty answering any specific items.

Instructions to Respondents

Instruct respondents as follows: "For each of the following, please indicate your level of confidence in doing the activity without losing your balance or becoming unsteady by choosing one of the percentage points on the scale from 0% to 100%. If you do not currently do the activity in question, try to imagine how confident you would be if you had to do the activity. If you normally use a walking aid to do the activity or hold onto someone, rate your confidence as if you were using these supports. If you have any questions about answering any of the items, please ask the administrator."

Instructions for Scoring

Total the ratings (possible range 0–1,600) and divide by 16 (or the number of items completed) to get each person's ABC Scale score. If a person qualifies his or her response to items 2, 9, 11, 14, or 15 (different ratings for up versus down or onto versus off), solicit separate ratings and use the lowest confidence rating of the two, which will limit the entire activity (eg, likelihood of using stairs). Total scores can be computed if at least 12 of the items are answered. Note that internal confidence (alpha) does not decrease appreciably with the deletion of item 16 (icy sidewalks) for administration in warmer climates.[13]

Development and Psychometric Properties

The ABC Scale was developed inductively with older adults and therapists, with evidence for test-retest reliability, hierarchical ordering, ability to discriminate between fallers and nonfallers, and high- versus low-mobility groups, and

FORM 3-1

THE ACTIVITIES-SPECIFIC BALANCE CONFIDENCE (ABC) SCALE

For <u>each</u> of the following activities, please indicate your level of self-confidence by choosing a corresponding number from the following rating scale:

| 0% | 10 | 20 | 30 | 40 | 50 | 60 | 70 | 80 | 90 | 100% |

No   **Completely**
Confidence   **Confident**

How confident are you that you can maintain your balance and remain steady when you . . .

1.   walk around the house? _____ %

2.   walk up or down stairs?_____ %

3.   bend over and pick up a slipper from the front of a closet floor? _____ %

4.   reach for a small can off a shelf at eye level? _____ %

5.   stand on your tip toes and reach for something above your head? _____%

6.   stand on a chair and reach for something?_____ %

7.   sweep the floor?_____ %

8.   walk outside the house to a car parked in the driveway?_____ %

9.   get into or out of a car?_____ %

10.   walk across a parking lot to the mall?_____ %

11.   walk up or down a ramp?_____ %

12.   walk in a crowded mall where people rapidly walk past you?_____ %

13.   are bumped into by people as you walk through the mall?_____ %

14.   step onto or off of an escalator while holding onto a railing?_____ %

15.   step onto or off an escalator while holding onto parcels such that you cannot hold onto the railing?_____ %

16.   walk outside on icy sidewalks?_____ %

association with balance performance measures.[12] ABC Scale scores above 50 and less than 80 are indicative of a moderate level of functioning characteristic of persons with chronic conditions. Scores above 80 indicate higher functioning, usually in active older adults, and are achievable through exercise and rehabilitative therapy.[12] The ABC Scale (and its cultural adaptations) continues to be widely used for various populations (eg, stroke).

Selected Reference

Powell LE, Myers AM. The Activities-specific Balance Confidence (ABC) Scale. *J Gerontol Med Sci*. 1995;50(1):M2834.

SINGLE-LIMB STANCE TEST

Purpose/Description

The Single-Limb Stance (SLS) Test, also called the Unipedal Stance Test, is a simple physical performance test of static balance ability.

Recommended Instrument Use

This simple test of static equilibrium is typically used as part of a battery of balance assessments.

Administration Protocol/Equipment/Time

The SLS Test requires a stopwatch and a flat surface. It takes less than 5 minutes, depending on the number of trials and limbs tested (Exhibit 3-2).

Groups Tested With This Measure

This test has been used to predict falls; to assess patients with chronic pain, peripheral neuropathy, Parkinson's disease, multiple sclerosis, and vestibular disorders; in community-dwelling elderly; as a measure of frailty; following ankle fracture, brain injury, stroke, and concussion; and for testing health-related fitness.[24]

Interpretability

Norms: Table 3-1 is a subset of the data most relevant to the ages of typical military personnel taken from Table 1 in Springer et al.[24] Testing was done for a maximum of 45 seconds. Subjects crossed their arms and were asked to look at a spot on the wall. Table 3-2 provides additional norms for 30-second maximum test times from Bohannon et al (1984; Tables 3-1 and 3-2).

MDC: eyes open = 5.3 seconds; eyes closed = 16.8 seconds (patients with acute unilateral vestibular loss). These minimal detectable change estimates were calculated from data from Kammerlind et al using patients with unilateral vestibular loss.[25]

MDC was not available for normal subjects or those with concussion. If the patient's score is less than the MDC value, it is considered indistinguishable from measurement error.

Responsiveness Estimates

An effect size of 0.57 and a response mean of 0.79 for change over 8 weeks were found in patients with non-peripheral vertigo and unsteadiness.[25]

Reliability Estimates

- Internal consistency: not available
- Interrater: ICC = 0.99 for eyes open and eyes closed in 50 healthy subjects between 19 and over 80 years old for the best of three trials; ICC = 0.95 for the mean of three trials for eyes closed; ICC = 0.83 for eyes closed mean of 3 trials[24]
  - ◦ ICC = 0.98 in 30 patients with acute unilateral vestibular loss with eyes open.
  - ◦ ICC = 1.0 in 30 patients with acute unilateral vestibular loss with eyes closed.
  - ◦ ICC = 1.0 in 20 patients with central neurological dysfunction with eyes open.
  - ◦ ICC = 0.99 in 20 patients with central neurological dysfunction with eyes closed.[25]
- Intrarater: r = 0.93 on retest within 1 week[26]
- Test-Retest
  - ◦ ICC = 0.92 in 30 patients with acute unilateral vestibular loss with eyes open.
  - ◦ ICC = 0.56 in 30 patients with acute unilateral vestibular loss with eyes closed.
  - ◦ ICC = 0.96 in 20 patients with central neurological dysfunction with eyes open.

EXHIBIT 3-2

RECORD OF FINDINGS FOR SINGLE-LIMB STANCE TEST

- Subject should stand on a flat surface without shoes, or with firm-bottomed shoes with no or low heels.
- Arms should be at the subject's sides, at hips.
- Timing begins on lifting of the nonstance limb.
- Timing ends:
  - with floor contact of the raised limb, or
  - touching of the raised limb to the stance leg, or
  - touching of wall or other support to prevent a fall.
- Timing stops at 45 seconds.
- Use the best of three trials.

Note: Patient can be tested with eyes open and again with eyes closed. One or both limbs may be assessed.

EYES OPEN:

Trial 1 _____   Trial 1 _____

Trial 2 _____   Trial 2 _____

Trial 3 _____   Trial 3 _____

Right (seconds to 0.1) _____ Left (seconds to 0.1) _____

EYES CLOSED:

Trial 1 _____   Trial 1 _____

Trial 2 _____   Trial 2 _____

Trial 3 _____   Trial 3 _____

Right (seconds to 0.1) _____ Left (seconds to 0.1) _____

TABLE 3-1

UNIPEDAL STANCE TIME NORMATIVE VALUES

Age	Gender	Eyes Open, Best of 3 Trials (sec) Mean (SE)	Eyes Open, Mean of 3 Trials (sec) Mean (SE)	Eyes Closed, Best of 3 Trials (sec) Mean (SE)	Eyes Closed, Mean of 3 Trials (sec) Mean (SE)
18–39	Female (n = 44)	45.1 (0.1)	43.5 (3.8)	13.1 (12.3)	8.5 (9.1)
	Male (n = 54)	44.4 (4.1)	43.2 (6.0)	16.9 (13.9)	10.2 (9.6)
40–49	Female (n = 47)	41.6 (0.1)	40.4 (10.1)	13.5 (12.4)	7.4 (6.7)
	Male (n = 51)	41.9 (9.9)	40.1 (11.5)	12.0 (13.5)	7.3 (7.4)

SE: standard error
Reproduced with permission from: Springer BA, Marin R, Cyhan T, Roberts H, Gill NW. Normative values for the unipedal stance test with eyes open and closed. *J Geriatr Phys Ther*. 2007;30(1):8–15.

TABLE 3-2

SUMMARY STATISTICS FROM ONE-LEGGED TIMED BALANCE TESTS OF SUBJECTS*

Decade	Eyes	$\overline{X} \pm s$	Minimum	First Quartile	Median	Third Quartile	Maximum	< 30 sec (%)
20–29	Opened	30.0±	•••	•••	•••	•••	•••	0
	Closed	28.8±2.3	22.5	28.6	•••	•••	•••	25
30–39	Opened	30.0±	•••	•••	•••	•••	•••	0
	Closed	27.8±5.0	8.4	29.9	•••	•••	•••	23
40–49	Opened	29.7±1.3	23.0	•••	•••	•••	•••	6
	Closed	24.2±8.4	3.5	18.9	•••	•••	•••	24
50–59	Opened	29.4±2.9	14.3	•••	•••	•••	•••	6
	Closed	21.0±9.5	5.1	11.9	24.8	•••	•••	57
60–69	Opened	22.5±8.6	4.8	17.0	24.6	•••	•••	57
	Closed	10.2±8.6	2.1	4.5	7.1	12.5	•••	90
70–79	Opened	14.2±9.3	1.2	4.9	12.2	21.6	•••	90
	Closed	4.3±3.0	0.7	2.3	3.4	5.4	12.7	100

*Time in seconds. Best of five trials used with counting stopping at 30 seconds. 30–32 subjects in each decade.
Reproduced with permission from: Bohannon RW, Larkin PA, Cook AC, Gear J, Singer J. Decrease in timed balance test scores with aging. *Phys Ther.* Jul 1984;64(7):1067–1070. The American Physical Therapy Association. This material is copyrighted and any further reproduction or distribution requires written permission from APTA.

- ○ ICC = 0.72 in 20 patients with central neurological dysfunction with eyes closed.[25]

Validity Estimates

- Content/Face: SLS is a component of a number of other balance scales.[27]
- Criterion: SLS time correlates significantly with ABC Scale (r = 0.41), tandem stance (r = 0.55), and Timed Up and Go (r = – 0.38), in 167 independent-living residents.[28]
- Construct: SLS time distinguishes between age groups[24,29]; distinguishes patients with known pathologies (ie, peripheral neuropathy) that would be expected to negatively affect balance.[30] SLS time identifies fallers.[30] SLS time correlates significantly with the Timed Up and Go without (r = 0.40) and with concurrent cognitive tasks (r = 0.27) in community-dwelling women over 70 years old.[31]

Selected Reference

Springer BA, Marin R, Cyhan T, Roberts H, Gill NW. Normative values for the unipedal stance test with eyes open and closed. *J Geriatr Phys Ther*. 2007;30(1):8–15.

ROMBERG AND SHARPENED ROMBERG

Purpose/Description

The Romberg and Sharpened Romberg tests are physical performance Tests used to assess a person's ability to maintain an upright posture with a stable and then a narrowed base of support (Exhibit 3-3).

Recommended Instrument Use

Neurologists are familiar with this test. The original Romberg has been used clinically for balance testing since the 1850s.[32]

Groups Tested With This Measure

This test has been used on healthy men and women,[33,34] for predicting falls,[35,36] on persons with dizziness and unsteadiness,[37] on persons with Parkinsonism,[38] and on those with vestibular disorders after traumatic brain injury.[39]

Administration Protocol/Equipment/Time

Subjects may cross their arms or hold their arms by their sides; timing begins after the subject

EXHIBIT 3-3

PROTOCOL RECORD OF FINDINGS FOR ROMBERG/SHARPENED ROMBERG TEST

Testing Protocol:

- Subject should stand without shoes on.
- Subjects may cross their arms or hold their arms by their sides.
- Timing begins after the subject assumes the proper position.
- Timing is stopped:
  ◦ if subjects move their feet from the original (proper) position,
  ◦ if they open their eyes on the eyes-closed trials, or
  ◦ if they reach the maximum balance time of 60 seconds (record to the 0.1 second).
- Four conditions are measured. The four test positions include:

Romberg	TRIAL 1	TRIAL 2	Average
1. Feet together, eyes open, 60 seconds (R-EO)	_____	_____	_____
2. Feet together, eyes closed, 60 seconds (R-EC)	_____	_____	_____

Sharpened Romberg	TRIAL 1	TRIAL 2	Average
3. Feet heel to toe, eyes open, 60 seconds (SR-EO) (dominant foot behind nondominant foot)	_____	_____	_____
4. Feet heel to toe, eyes closed, 60 seconds (SR-EC) (dominant foot behind nondominant foot)	_____	_____	_____

Patient Instructions (Eyes Open, Romberg)

Stand with both anklebones touching each other, with your hands crossed and touching the opposite shoulders. Stand without shoes on, if possible, and look straight ahead at a target about 3 feet in front of you. Try to stay in this position for 60 seconds.

Instructions for the Patient (Eyes Closed, Romberg)

Stand with both anklebones touching each other, with your hands crossed and touching the opposite shoulders. Stand without shoes on, if possible, and look straight ahead with your eyes closed. Try to stay in this position for 60 seconds. **Note**: These tests can also be done with a 30-second maximum limit.

R-EC: Romberg, eyes closed
R-EO: Romberg, eyes open
SR-EC: Sharpened Romberg, eyes closed
SR-EO: Sharpened Romberg, eyes open

assumes the proper position. Four conditions are measured. Timing is stopped if subjects move their feet from the original (proper) position, if they open their eyes on the eyes-closed trials, or if they reach the maximum balance time of 60 seconds (note that some scenarios use a maximum balance time of 30 seconds).[40] Two trials can be given and the longest balance time recorded. The test positions are as follows: for Romberg, 1) feet together, eyes open, 60 seconds (Romberg, eyes open); 2) feet together, eyes closed, 60 seconds (Romberg, eyes closed); and for sharpened Romberg, 1) feet heel to toe, eyes open, 60 seconds (Sharpened Romberg, eyes open; dominant foot behind nondominant foot); 2) feet heel to toe, eyes closed, 60 seconds (Sharpened Romberg, eyes closed; dominant foot behind nondominant foot).

TABLE 3-3

TANDEM ROMBERG (EYES CLOSED)

Decade	Mean	Standard Deviation	Median	Percent 30 Sec	Percent 10 Sec
3 (n = 58)	29.94	.43	30.00	98	100
4 (n = 42)	30.00	.00	30.00	100	100
5 (n = 32)	28.82	4.66	30.00	94	97
6 (n = 28)	28.03	4.87	30.00	82	100

Data source: Vereeck L, Wuyts F, Truijen S, Van de Heyning P. Clinical assessment of balance: normative data, and gender and age effects. *Int J Audiol.* Feb 2008;47(2):67–75.

Interpretability

Norms: Table 3-3 provides a subset of the normative values on tandem Romberg tested with eyes closed.[37] Additional normative values for older adults (50 years of age and older) can be found in Steffen and Mollinger (Table 3-4).[41] No younger groups were tested.

$MDC_{95\%}$: 9 to 10 seconds in sharpened Romberg with eyes open and 3 to 9 seconds with eyes closed in subjects with central and peripheral vestibular dysfunction.[25] If the patient's score is less than the MDC value, it is considered indistinguishable from measurement error.

Responsiveness Estimates

Twenty nonexercising community dwellers (ages 58–68) showed a 4.9-second improvement in Sharpened Romberg following a 3-month program of 1 hour, twice weekly Caribbean dance exercise, compared to 20 community dwellers with no physical activity.[42]

Reliability Estimates

- Internal consistency: not applicable

- Interrater: eyes open r = 0.75, eyes closed r = 0.97[34]; 30 patients with acute vestibular loss[25]; Sharpened Romberg, eyes open, ICC = 1.00; Sharpened Romberg, eyes closed, ICC = 0.99
- Intrarater: 45 women with eyes open and eyes closed ICC (2,1) = 0.99[34]
- Test-Retest: 30 subjects with unilateral vestibular loss doing Sharpened Romberg, eyes closed ICC = 0.63; Sharpened Romberg, eyes open ICC = 0.76[25]; 19 subjects between 24 and 39 years old (examining aviation simulator sickness): ICC (2,1) = 0.72 with eyes closed and ICC (2,1) = 0.90 with eyes open[43]

Validity Estimates

- Content/Face: The sharpened Romberg came to be used in the 1940s as a posture requiring a higher-level skill than the Romberg.[44]
- Criterion: Elderly females with a history of falls had significantly lower scores on sharpened Romberg with eyes open than did elderly female nonfallers.[36]
- Construct: not available

TABLE 3-4

TANDEM ROMBERG: OLDER ADULTS

Age/Gender	Sharpened Rhomberg, Eyes Open			Sharpened Rhomberg, Eyes Closed		
50–59	**Mean**	**SD**	**CI (95%)**	**Mean**	**SD**	**CI (95%)**
Male (n = 9)	60	0	60-60	51	18	37-60
Female (n = 15)	56	15	48-64	37	22	24-49

CI: confidence interval
SD: standard deviation
Data source: Steffen TM, Mollinger LA. Age- and gender-related test performance in community-dwelling adults. *J Neurol Phys Ther*. Dec 2005;29(4):181–188.

Selected References

Romberg MH. Manual of Nervous System Diseases of Man. London, England: Sydenham Society. 1853:395–401.

Black FO, Wall C, Rockette HE, Kitch R. Normal subject postural sway during the Romberg test. *Am J Otolaryngol*. 1982;3(5):309–315.

BALANCE ERROR SCORING SYSTEM

Purpose/Description

The Balance Error Scoring System (BESS) is a physical performance test that uses modified Romberg stances on different surfaces to assess postural stability (Exhibit 3-4). It was developed as a practical and cost-effective method of assessing balance at the sidelines in athletes, primarily to assist in return-to-play decisions following concussion.[45]

Recommended Instrument Use

The BESS can be used for a quick evaluation of postural control in service members as a component of a battery of tests to determine return-to-duty status.[46] A practice effect has been reported on repeat administrations of the BESS, particularly with the single-leg stance on foam.[47] The environment for baseline testing may affect the BESS score. Baseline testing for postural control using the BESS should be conducted "in the setting or environment in which post injury testing will most likely take place," as it has been shown that normal subjects' performance was worse when tested at the sideline versus in a clinical environment.[48]

Administration Protocol/Equipment/Time

The test consists of three stance conditions (double leg, single leg, and tandem) and two surfaces (firm and foam) assessed for 20 seconds each; each stance condition is completed with eyes closed. A stopwatch and a medium-density foam square (50 cm × 41 cm × 6 cm thick) are the only equipment needed. Scoring is done by counting the number of errors during each trial. Each error counts as one point and the total score is the sum of all the errors. Depending on a subject's ability and the number of errors, testing takes 5 to 10 minutes. No formal training is required to administer the BESS. A higher score indicates a poorer performance, with the very best performance resulting in a score of 0.[45]

Groups Tested With This Measure

Those tested with the BESS include high school and college athletes,[47–49] young athletes between the ages of 9 and 14,[50] and community-dwelling adults between the ages of 29 and 65.[51]

Interpretability

- Norms: Iverson et al have recently presented normative data for community-dwelling adults from age 20 to 69.[52] Data most relevant to service members are presented in Table 3-5.
- MDC: Reliable change indices are as follows[50]:
  - 90% CI = − 9.4 or + 5.3 points
  - 80% CI = − 7.9 or + 3.8 points
  - 70% CI = − 6.8 or + 2.6 points
  - 7.3 points (videotaped athletes–intrarater reliability data)[53]

If the patient's score is less than the MDC value, it is considered indistinguishable from measurement error.

Responsiveness Estimates

In collegiate football players following concussion, BESS scores changed from baseline, on average 5.7 points (95% CI) when measured immediately following the game or practice in which the injury occurred.[49]

Reliability Estimates

- Internal consistency: not available
- Interrater: ICC = 0.78–0.93 in control subjects for BESS subscores[54]; ICC = 0.57 for total BESS score (errors) using videotape of 30 athletes.[53] A lack of errors in some conditions (eg, double-leg stance on firm surface) did not allow calculation of rater reliability for that condition.
- Intrarater: ICC = 0.74 for total BESS score (errors) using videotape of 30 athletes.[53] ICC = 0.87–0.98 for total BESS and BESS subscores with a single tester viewing 20 videotaped subjects on two different days.[50]

EXHIBIT 3-4

BALANCE ERROR SCORING SYSTEM INSTRUCTIONS

Developed by researchers and clinicians at the University of North Carolina's Sports Medicine Research Laboratory, Chapel Hill, NC 27599-8700. The following is reproduced with permission from K Guskiewicz, April 26, 2010.[45]

The Balance Error Scoring System provides a portable, cost-effective, and objective method of assessing static postural stability. In the absence of expensive, sophisticated postural stability assessment tools, the BESS can be used to assess the effects of mild head injury on static postural stability. Information obtained from this clinical balance tool can be used to assist clinicians in making return-to-play decisions following mild head injury.

The BESS can be performed in nearly any environment and takes approximately 10 minutes to conduct.

Materials

1. Testing surfaces
    Two testing surfaces are needed: floor/ground and foam pad.
    1a. Floor/ground: any level surface is appropriate.
    1b. Foam pad: Power Systems Airex Balance Pad 81000 (Power Systems, Inc, Knoxville, TN); dimensions: length: 10 inches; width: 10 inches; height: 2.5 inches

The purpose of the foam pad is to create an unstable surface and a more challenging balance task, which varies by body weight. It has been hypothesized that as body weight increases the foam will deform to a greater degree around the foot. The heavier the person, the more the foam will deform. As the foam deforms around the foot, there is an increase in support on the lateral surfaces of the foot. The increased contact area between the foot and foam has also been theorized to increase the tactile sense of the foot, also helping to increase postural stability. The increase in tactile sense will cause additional sensory information to be sent to the CNS [central nervous system]. As the brain processes this information it can make better decisions when responding to the unstable foam surface.

2. Stopwatch
    Necessary for timing the subjects during the six 20-second trials

3. An assistant to act as a spotter
    The spotter is necessary to assist the subject should they become unstable and begin to fall. The spotter's attention is especially important during the foam surface.

4. BESS Testing Protocol
    These instructions should be read to the subject during administration of the BESS.

5. BESS Score Card

BESS Test Administration

1. Before administering the BESS, the following materials should be present:
    *   foam pad
    *   stopwatch
    *   spotter
    *   BESS Testing Protocol
    *   BESS Score Card
2. Before testing, instruct the individual to remove shoes and any ankle taping if necessary. Socks may be worn if desired.
3. Read the instructions to the subject as they are written in the BESS Testing Protocol.
4. Record errors on the BESS Score Card as they are described below.

(**Exhibit 3-4** *continues*)

Exhibit 3-4 *continued*

BALANCE ERROR SCORING SYSTEM (SCORE CARD)

Types of Errors

1. Hands lifted off iliac crest
2. Opening eyes
3. Step, stumble, or fall
4. Moving hip into greater than 30 degrees abduction
5. Lifting forefoot or heel
6. Remaining out of test position greater than 5 seconds

SCORE CARD		
Error	**Firm Surface**	**Foam Surface**
Double leg stance (feet together)		
Single leg stance (nondominant foot)		
Tandem stance (nondominant foot in back)		
Total score		
BESS TOTAL		

The BESS is calculated by adding one error point for each error during the 6-20 second test.

Scoring the BESS

Each of the 20-second trials is scored by counting the errors, or deviations from the proper stance, accumulated by the subject. The examiner will begin counting errors only after the individual has assumed the proper testing position.

Errors: An error is credited to the subject when any of the following occur:

- moving the hands off of the iliac crests
- opening the eyes
- step stumble or fall
- abduction or flexion of the hip beyond 30°
- lifting the forefoot or heel off of the testing surface
- remaining out of the proper testing position for greater than 5 seconds

The maximum total number of errors for any single condition is 10.

Normal Scores for Each Possible Testing Surface (Table)

Maximum Number of Errors Possible for Each Testing Surface (Table)

If a subject commits multiple errors simultaneously, only one error is recorded. For example, if an individual steps or stumbles, opens their eyes, and removes their hands from their hips simultaneously, then they are credited with only one error.

(**Exhibit 3-4** *continues*)

Exhibit 3-4 *continued*

Subjects that are unable to maintain the testing procedure for a minimum of 5 seconds are assigned the highest possible score, 10, for that testing condition.

Double-leg stance: standing on a firm surface with feet side by side (touching), hands on the hips and eyes closed (Figures 1 and 2).
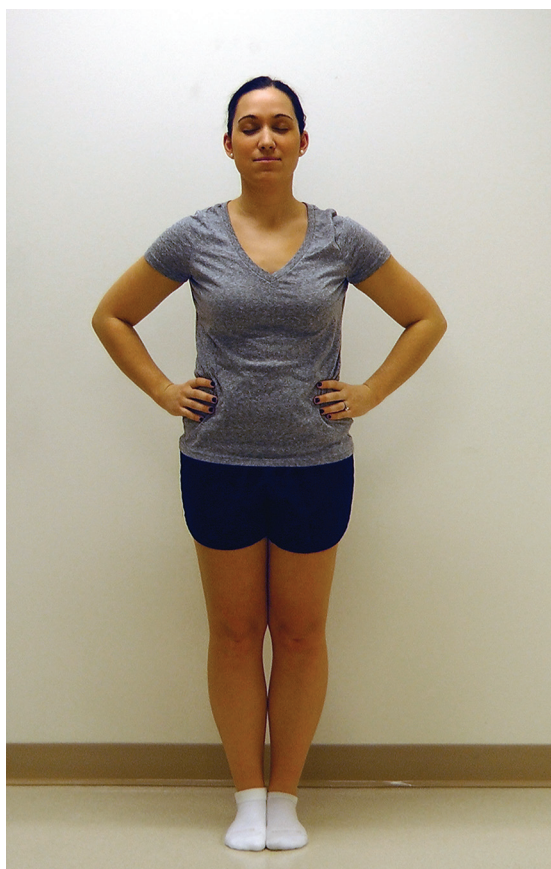
Single-leg stance: standing on a firm surface on the nondominant foot (defined below), the hip is flexed to approximately 30° and knee flexed to approximately 45°. Hands are on the hips and eyes closed (Figures 3 and 4).

*Nondominant foot: the nondominant foot is defined as the opposite leg of the preferred kicking leg.

Tandem stance: standing heel to toe on a firm surface with the nondominant foot (defined above) in the back. Heel of the dominant foot should be touching the toe of the nondominant foot. Hands are on the hips and their eyes are closed (Figures 5 and 6).

Figure 1. Balance Error Scoring System, double-leg stance, flat surface.

Script for the BESS Testing Protocol

Direction to the subject: *I am now going to test your balance.*

Please take your shoes off, roll up your pant legs above ankle (if applicable), and remove any ankle taping (if applicable).

This test will consist of six 20-second tests with three different stances on two different surfaces. I will describe the stances as we go along.

Double-Leg Stance

Direction to the subject: *The first stance is standing with your feet together like this*. [Administrator demonstrates two-legged stance.]

Figure 2. Balance Error Scoring System, double-leg stance, foam surface.

(**Exhibit 3-4** *continues*)
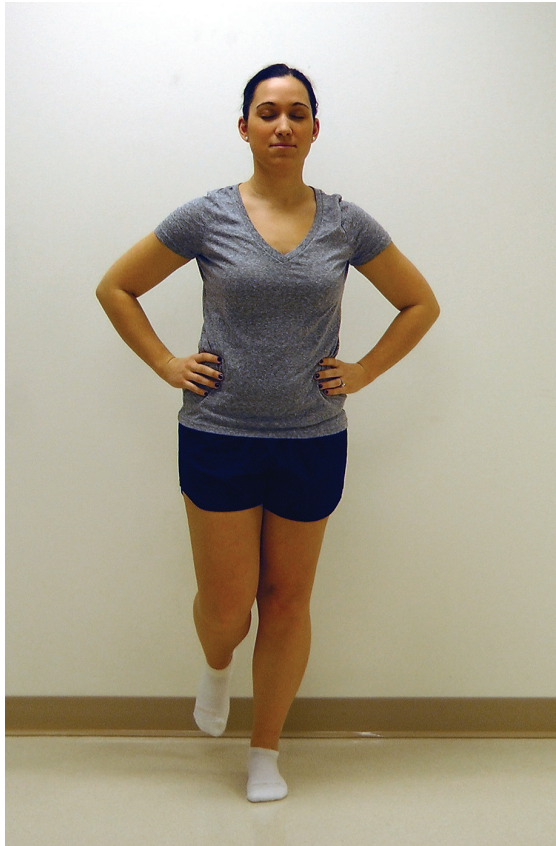
Exhibit 3-4 *continued*

Figure 3. Balance Error Scoring System, single-leg stance, flat surface.

Single-Leg Stance

Direction to subject: *If you were to kick a ball, which foot would you use?* [This will be the dominant foot.]

Now stand on your nondominant foot.

[Before continuing the test, assess the position of the dominant leg as such: the dominant leg should be held in approximately 30° of hip flexion and 45° of knee flexion.]

Again, you should try to maintain stability for 20 seconds with your eyes closed. I will be counting the number of times you move out of this position.

Place your hands on your hips. When you close your eyes the testing time will begin.
[Start timer when subject closes their eyes.]

Direction to the spotter: *You are to assist the subject*

You will be standing with your hands on your hips with your eyes closed. You should try to maintain stability in that position for entire 20 seconds. I will be counting the number of times you move out of this position. For example: if you take your hands off your hips, open your eyes, take a step, lift your toes or your heels. If you do move out of the testing stance, simply open your eyes, regain your balance, get back into the testing position as quickly as possible, and close your eyes again.

There will be a person positioned by you to help you get into the testing stance and to help if you lose your balance.

Direction to the spotter: *You are to assist the subject if they fall during the test and to help them get back into the position.*

Direction to the subject: *Put your feet together, put your hands on your hips and when you close your eyes the testing time will begin.* [Start timer when subject closes their eyes.]
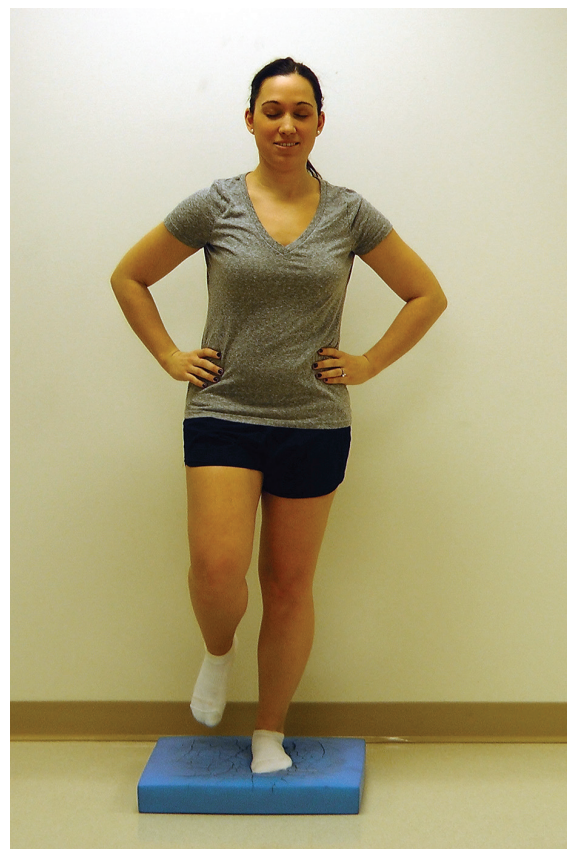

Figure 4. Balance Error Scoring System, single-leg stance, foam surface.

(**Exhibit 3-4** *continues*)

Exhibit 3-4 *continued*

Figure 5. Balance Error Scoring System, tandem stance, flat surface.

Figure 6. Balance Error Scoring System, tandem stance, foam surface.

if they fall during the test and to help them get back into the position.

Tandem Stance

    <u>**Directions to the subject**</u>: *Now stand heel to toe with your nondominant foot in back. Your weight should be evenly distributed across both feet.*

    Again, you should try to maintain stability for 20 seconds with your eyes closed. I will be counting the number of times you move out of this position.

    Place your hands on your hips. When you close your eyes the testing time will begin.
[Start timer when subject closes their eyes.]

    <u>**Direction to the spotter**</u>: *You are to assist the subject if they fall during the test and to help them get back into the position.*

    *** Repeat each set of instructions for the foam pad
Note which foot was tested: . . . Left . . . Right (ie, which is the **nondominant** foot)

TABLE 3-5

NORMATIVE DATA FOR BALANCE ERROR SCORING SYSTEM (ERRORS)[*]

Age	Mean	Median	Standard Deviation	Superior (> 90th Percentile)	Broadly Normal (25–75 Percentile)	Poor (2nd–9th Percentile)
20–29 (n = 65)	11.3	11.0	4.8	0–5	8–14	18–23
30–39 (n = 173)	11.5	11.0	5.5	0–4	8–15	19–26
40–49 (n = 352)	12.5	11.5	6.2	0–5	9–16	21–28

[*]Iverson and Koehle recently presented normative data for community-dwelling adults from ages 20 to 69. Data most relevant to service members is presented here.
Data source: Iverson GL, Koehle MS. Normative data for the balance error scoring system in adults. *Rehabil Res Practice*. 2013;2013:846418.

- Test-Retest: In fifty 9- to 14-year-old athletes, BESS (errors) ICC (2,1) = 0.70, (SEM = 3.17).[50]

Validity Estimates

- Content/Face: not available
- Criterion: There are significant correlations between the BESS and force platform sway measures using normal subjects.[45]
- Construct: There is a small to medium correlation between age and BESS (r = 0.36).[51]

Selected References

Guskiewicz KM. Postural stability assessment following concussion: one piece of the puzzle. *Clin J Sport Med*. 2001;11:182–189.

Bell, DR, Guskiewicz KM, Clark MA, Padua DA. Systematic review of the Balance Error Scoring System. *Sports Health: A Multidisciplinary Approach*. 2011;3(3)287–295.

MODIFIED CLINICAL TEST OF SENSORY INTERACTION ON BALANCE

Purpose/Description

The Modified Clinical Test of Sensory Interaction on Balance (mCTSIB) is a physical performance test that attempts to differentiate the relative contribution of the somatosensory, visual, and vestibular systems to maintaining standing balance.[5] The original test was modified from six conditions to four.

Recommended Instrument Use

The mCTSIB is a useful screening tool for identifying persons with abnormal postural control and abnormal use of sensory inputs for balance control in standing.

Administration Protocol/Equipment/Time

The mCTSIB requires a stopwatch and dense foam pad (typically a 16-inch square, 3 to 4 inches high, medium-density foam that does not bottom out). Testing is done under four conditions, with a maximum of three trials per condition, each up to 30 seconds. Scoring involves recording the time (in seconds) to complete each trial. The times are then summed for a total mCTSIB score (maximum score 120 seconds for all four conditions). Higher scores indicate better performance of sensory interaction and balance. Depending on the subject's ability and how many trials are needed, testing takes 5 to 15 minutes. No formal training is required to administer the mCTSIB.

Groups Tested With This Measure

The mCTSIB has been used to evaluate individuals undergoing vestibular physical therapy,[55] physical therapy students and faculty, community-dwelling elderly, and those with vestibular disorders.[56] It has also been used to determine fall risk in older adults[57] and to assess those with peripheral neuropathy.[58]

Interpretability

- Norms: Subjects between the ages of 20 and 24, 25 and 44, and 45 and 64 years of age were able to maintain balance for 30 seconds in all four conditions.[56] Subjects in the 65-to-84-year-old range were able to stand on a firm surface with eyes open and closed for 30 seconds. These older subjects had significantly lower time when on foam with eyes open and eyes closed.
  Thirty subjects between 23 and 81 years old (mean 58.1 +/− 17.1) with both peripheral and central vestibular disorders, with a mean DHI score of 43.0 (+/−19.6) showed the following time (in seconds) during the mCTSIB with feet shoulder-width apart[55]:
  - Firm surface with eyes open: 30.0 +/− 0.0
  - Firm surface with eyes closed: 29.0 +/−3.9
  - Foam with eyes open: 29.0 +/− 4.1
  - Foam with eyes closed: 25.2 +/− 9.3
    Using the Sensory Organization Test (SOT) total scores as criterion, the mCTSIB had a sensitivity of 88% in both open (feet shoulder-width apart) and closed (feet together) stance, with a specificity of 50% when performed in a closed stance and a specificity of 44% when performed in an open stance.[59]
- MDC: not available. If the patient's score is less than the MDC value, it is considered indistinguishable from measurement error.

Responsiveness Estimates

This test is a screening tool that assesses a person's ability to use sensory inputs for balance control in standing. The mCTSIB, in combination with single-leg stance, and tandem Romberg in eyes open and closed conditions, has been used to monitor change over time in a group of vestibular patients[60]; however, studies that use the mCTSIB alone for responsiveness to change were not found.

Reliability Estimates

- Internal consistency: not available
- Interrater: r =0.99 with testing done on five physical therapy students (ages 20–24 years)[56]; r = 0.75 in older, community-dwelling adults[57]
- Intrarater: not available
- Test-Retest: r = 0.99 with testing done on five physical therapy students (ages 20–24 years)[56]

Validity Estimates

- Content/Face: not available
- Criterion: In a group of 50 patients with vestibular complaints, foam posturography demonstrated a significant correlation (P < 0.005) with moving platform posturography as the gold standard (90% agreement). A sensitivity of 95% and specificity of 90% were found between the foam posturography and the gold standard of the SOT on the moving platform.[61] In a group of patients undergoing vestibular rehabilitation, correlations between CTSIB and SOT range from 0.41 to 0.89 tested over the duration of the treatment.[60] The mCTSIB performed with feet together was slightly more sensitive than the mCTSIB performed with feet apart and correlated better with the SOT in persons with vestibular disorders.[59]
- Construct: The mCTSIB has been used to determine fall risk in older adults.[57] When subjects were age matched, no differences were found on condition 4 (eyes open on foam) between asymptomatic subjects and vestibular-impaired subjects.[56]

Performing the Test

This test provides a preliminary assessment of how well a person can integrate vestibular, visual, and somatosensory input for maintaining postural balance and how well the person can compensate when one or more of these senses is compromised.

Condition 1: three sensory systems available for balance (vision, vestibular, somatosensory)

Condition 2: vestibular and somatosensory available, vision absent

Condition 3: vestibular and vision available, somatosensory compromised

Condition 4: vestibular available, vision absent, somatosensory compromised

Equipment

Necessary equipment includes a stopwatch and dense foam pad, typically a 16-inch square, 3 to 4 inches high, medium-density foam that does not bottom out.

Starting Position

The subject stands on foam with his or her feet shoulder-width apart and arms crossed over the chest.

Protocol

Use the stopwatch to time a 30-second trial. Time is stopped and recorded if the subject:

- deviates from initial crossed-arm position,
- opens eyes during an "eyes closed" trial condition, or
- moves feet (takes a step) or requires manual assistance to prevent loss of balance.

A successful trial is recorded if the subject independently maintains the starting position for 30 seconds. Perform a maximum of three trials, or until the subject either maintains the starting position for 30 seconds or completes three 30-second attempts.

Scoring

Record the time (in seconds) that the subject was able to maintain the starting position up to the maximum of 30 seconds. The total score is the time recorded for each condition (maximum 120 seconds for all four conditions), or if more than one trial was performed for each condition, add the average times of each condition (maximum 120 seconds for all four conditions, Exhibit 3-5).

EXHIBIT 3-5

MODIFIED CLINICAL TEST OF SENSORY INTERACTION ON BALANCE

#A -EYES OPEN, FIRM SURFACE

Trial 1:_____sec

Trial 2:_____sec   Average score (Total 3 trials/3):   sec

Trial 3:_____sec

#B -EYES CLOSED, FIRM SURFACE

Trial 1:_____sec

Trial 2:_____sec   Average score (Total 3 trials/3):   sec

Trial 3:_____sec

#C -EYES OPEN, FOAM SURFACE

Trial 1:_____sec

Trial 2:_____sec   Average score (Total 3 trials/3):————sec

Trial 3:_____sec

#D -EYES CLOSED, FOAM SURFACE

Trial 1:_____sec

Trial 2:_____sec   Average score (Total 3 trials/3):_____sec

Trial 3:_____sec

Total score: _____/120 sec

(Use the average score for each condition if more than one trial was required).

Data source: Shumway-Cook A, Horak FB, Assessing the influence of sensory interaction on balance. *Phys Ther*. 1986;66:1548–1550.

Selected Reference

Shumway-Cook A, Horak FB. Assessing the influence of sensory interaction on balance. *Phys Ther*. 1986;66:1548–1550.

BALANCE EVALUATION SYSTEMS TEST

Purpose/Description

The BESTest is a physical performance test developed to differentiate balance deficits by identifying the underlying postural control systems responsible for poor functional balance. The premise is that by identifying the underlying systems contributing to different types of balance deficits, an appropriate and specific rehabilitation approach can be developed.[4] The areas of assessment include biomechanical constraints, stability limits/verticality, anticipatory postural movements, postural responses, sensory orientation, and stability in gait. The test is available at the developer's website (www.bestest.us) free of charge; a training disk is available for a fee and is highly recommended.

Recommended Instrument Use

The BESTest was developed to assess and treat patients (primarily the elderly) with different types of balance problems. Its purpose is to identify deficits in the six targeted balance control systems and develop intervention strategies based on the findings. The therapist may consider using the BESTest for service members with complex balance complaints.

Administration Protocol/Equipment/Time

The BESTest consists of 36 items grouped into 6 systems. These are measured using a stopwatch, tape measure, 10-degree incline ramp, foam block, performance, or observation. Measures obtained on each item are scored on a scale from 0 (worst performance) to 3 (best performance). Scores for each section and the total test are provided as a percentage of total points. Testing takes 30 minutes by an experienced therapist. Training for inexperienced raters (those with no physical therapy experience) is recommended. Learning to score the BESTest requires prior review and 45 minutes of instruction with demonstration.[4] Training can be obtained via DVD or by attending a training course (see www.ohsu.edu/xd/research/centers-institutes/neurology/parkinson-center/research/horak-lab-balance/bestest.cfm; or www.ohsu.edu/tech-transfer/portal/technology.php?technology_id=217191).

Groups Tested With This Measure

The BESTest has been used on 22 subjects with and without balance disorders, ranging in age from 50 to 88 years,[4] and on subjects with Parkinson's disease.[62]

Interpretability

- Norms: not available. Some portions of the BESTest are drawn from existing clinical tests and there may be normative data available on individual parts, but none is available on the BESTest in its entirety.
- MDC: not available. If the patient's score is less than the MDC value, it is considered indistinguishable from measurement error.

Responsiveness Estimates: not available

Reliability Estimates

- Internal consistency: not available
- Interrater: ICC = 0.91 on total score, with the ICC for six sections ranging from r = 0.79 to 0.96[4]
- Intrarater: not available
- Test-Retest: not available

Validity Estimates

- Content/Face: Many subcomponents are taken from existing balance assessments and placed in the theoretical framework. Thousands of therapists responded to early versions of the BESTest through a large number of continuing education courses.[4]
- Criterion: r = 0.636, correlation between the BESTest and the ABC scale in subjects (age 50 to 88 years old) with and without balance disorders.[4]
- Construct: not available

Selected References

Horak FB, Wrisley DM, James F. The Balance Evaluation Systems Test (BESTest) to differentiate balance deficits. *Phys Ther*. 2009;89(5):484–498.

Horak F. BESTest-Balance Evaluation-Systems Test. http://www.ohsu.edu/xd/research/centers-institutes/neurology/parkinson-center/research/horak-lab-balance/bestest.cfm. Accessed July 16, 2013.

MINI-BALANCE EVALUATION SYSTEMS TEST OF DYNAMIC BALANCE

The Mini-BESTest is a 14-item scale used to measure dynamic balance. It was developed following factor and Rasch analysis to eliminate redundant or insensitive items on the original BESTest[11] and to improve scoring and make the test shorter to administer. The 14 items in the mini-BESTest include tests in four of the six original targeted balance control systems: (1) anticipatory transitions, (2) postural responses, (3) sensory orientation, and (4) dynamic gait. The Rasch analysis and refinement was done to focus on "dynamic balance" and to separate psychometric analyses of parts I, "biomechanical constraints," and II, "stability limits" of the original BESTest.[11]

Recommended Instrument Use

The Mini-BESTest has been used primarily in older adults with different types of balance problems,[11] especially those with Parkinson's disease.[63,64] A therapist may consider using the Mini-BESTest for service members with subtle balance deficits, as it has shown promise in discerning subtle balance deficits in patients with early Parkinson's disease[65] without the same ceiling effects as the Berg Balance Test in this population.

Administration Protocol/Equipment/Time

The Mini-BESTest consists of 14 items grouped into four systems. It takes 10 to 15 minutes to administer and requires a stopwatch, tape measure, 10-degree incline ramp, shoe box, chair, and foam block (medium-density memory foam, 4 inches thick). It requires patient performance be observed by the therapist. Measures obtained on each item are scored on a scale of 0 (poor balance) to 2 (normal, no impairment of balance), with a maximum score of 28. Two of the test items score both the right and left sides by recording the worse side.[65]

Groups Tested With This Measure

The Mini-BESTest has been tested on a convenience sample of 115 subjects (mean age 62.7 years; 53 men, 62 women) with balance disorders of various etiologies (primarily hemiparesis, Parkinson's disease, other neuromuscular diseases, hereditary ataxia, and multiple sclerosis, etc).[11] The Mini-BESTest was more accurate in predicting falls than the Berg Balance Scale or the FGA during 6-month and 12-month prospective analyses in a group of 80 participants with idiopathic Parkinson's disease,[63] and identified those with mild Parkinson's disease better than the Berg Balance Scale.[65] Data on subjects with c/mTBI have not yet been published. The Mini-BESTest can be downloaded from the Internet (www.bestest.us/files/7413/6380/7277/MiniBEST_revised_final_3_8_13.pdf).

Interpretability

- Norms: not available; however, some portions of the Mini-BESTest are drawn from existing clinical tests and there may be normative data available on individual parts, but none is available on the Mini-BESTest in its entirety.
- MDC: not available. If the patient's score is less than the MDC value, it is considered indistinguishable from measurement error.

Responsiveness Estimates: not available

Reliability Estimates

- Internal consistency: not available
- Interrater: ICC r ≥ 0.91 on total score (n = 15 between three raters) in persons with Parkinson's disease[64]
- Intrarater: not available
- Test-Retest: ICC r ≥ 0.92 (n = 24) in persons with Parkinson's disease[64]

Validity Estimates

- Content/Face: Many subcomponents of the original BESTest are taken from existing balance assessments and placed in the theoretical framework. Thousands of therapists responded to early versions of the BESTest through a large number of continuing education courses.[4]
- Criterion: Tested on 97 persons with Parkinson's disease, the Mini-BESTest correlated significantly with the Berg Balance Scale (r = 0.79, P < 0.001).[65]
- Construct: The Mini-BESTest was able to distinguish between fallers and nonfallers in persons with Parkinson's disease.[63]
- Sensitivity/Specificity: A cut-off point for the Mini-BESTest to differentiate "those with and without postural response deficits ≥ 21, yielding (sensitivity, specificity) = (89%, 81%)."[65]

Selected Reference

Franchignoni F, Horak F, Godi M, Nardone A, Giordano A. Using psychometric techniques to improve the balance evaluations systems test: the Mini-BESTest. *J Rehab Med*. 2010;42:323–331.

COMPUTERIZED DYNAMIC POSTUROGRAPHY

Computerized dynamic posturography (CDP) involves the use of a sophisticated force platform system to study the contributions of the visual, vestibular, and somatosensory systems to maintaining postural stability. The protocols described in this toolkit are proprietary to NeuroCom (Clackamas, OR; www.resourcesonbalance.com/program/role/cdp/index.aspx), but there are other balance platform systems available (eg, Micromedical Balance Quest, Chatham, IL; www.micromedical.com/balancequest.html).

Using the NeuroCom platform, CDP includes the SOT, Motor Control Test (MCT), and Adaptation Test. The assessments described here for use in service members with c/mTBI are the SOT and the MCT.

Sensory Organization Test

The SOT portion of CDP systematically removes one or more sensory components of balance (vision, somatosensory, vestibular) to evaluate which component the client is reliant upon for balance. Certain patterns of dysfunction are associated with specific deficits and indicate a person's ability to suppress inappropriate visual and proprioceptive information. Patterns of response may also indicate a person's inability to weight appropriate sensory input to the specific test condition. The six evaluation conditions are as follows:

1) Condition 1: stable platform with eyes open in a stable visual environment (patient has full use of all information: visual, vestibular, and somatosensory).
2) Condition 2: stable platform with eyes closed (patient must rely on vestibular and somatosensory information).
3) Condition 3: stable platform with moving visual surround (patient must suppress a false sense of visually induced movement and rely on vestibular and somatosensory inputs).
4) Condition 4: unstable platform with eyes open in a stable visual environment (patient must rely on vestibular and visual inputs).
5) Condition 5: unstable platform with eyes closed (patient must rely on vestibular input only because visual and somatosensory feedback have been eliminated).
6) Condition 6: unstable platform and unstable visual environment (patient must rely on vestibular input alone and suppress a false sense of visually induced movement).[66]

The SOT report provides a composite equilibrium score, sensory analysis ratios, strategy analysis, and center of gravity alignment. The composite equilibrium score characterizes the subject's overall level of balance performance. The sensory analysis ratios help identify impairments of or reliance on individual sensory systems, including the somatosensory, visual, and vestibular systems. The strategy analysis evaluates the subject's appropriate use of hip or ankle strategies in response to support surface changes. Finally, the center-of-gravity position data provides information on the location of the subject's center of gravity relative to the base of support (see NeuroCom user's manual[67]).

Motor Control Test

The MCT measures a person's ability to reflexively recover from unexpected external surface provocations. The MCT report provides information on weight symmetry and the latency and amplitude of a patient's response to a perturbation. Weight symmetry evaluates the relative distribution of weight during perturbations, while latency and amplitude quantify the onset time and amplitude of response to small, medium, and large perturbations in forward and backward directions (see NeuroCom user's manual[67]).

Recommended Instrument Use

CDP should not be used in isolation, but in conjunction with clinical measures of balance to obtain a comprehensive view of a service member's balance deficits. Although there remain issues with fully characterizing the reliability, validity, and responsiveness of CDP for service members with c/mTBI, CDP, where available, can assist in a full description of and the progress or course of balance complaints can help practitioners describe and assess the progress of balance complaints. The American Academy of Otolaryngology—Head and Neck Surgery recognizes dynamic platform posturography as medically indicated and appropriate in evaluating those with suspected balance or dizziness disorders.

CDP protocols are often used to evaluate patients for aphysiologic responses, malingering, or exaggerated patterns of responses to testing. A number of criteria have been developed[68–70] to address the issue of sway patterns and postural responses that are out of proportion to the clinical assessments and laboratory findings of postural and gait control, given the presenting mechanism and severity of injury or diagnosis. These criteria include such findings as high intertrial variability, performance on "easier" SOT conditions (1 and 2) being worse than performance on more difficult conditions (5 and 6), and exaggerated motor responses to small translations that do not appropriately increase with the larger forward-and-backward translations and include the therapist's clinical judgment.[70]

Administration Protocol/Equipment/Time

The information provided here for the SOT and the MCT is only available through use of the NeuroCom Balance Master System. Testing takes 10 to 20 minutes.

Other companies that provide dynamic posturography that can allow testing of the modified clinical test of sensory organization on balance include Micromedical's Balance Quest (http://www.micromedical.com/balancequest.html)/

Groups Tested With This Measure

In addition to testing individuals with vestibular and other causes of balance disorders,[71,72] CDP has been used to quantify abnormalities in sensory weighting and postural sway in persons with mild to severe traumatic brain injury.[10,73,74] The SOT portion of CDP was used to assess balance deficits in 10 subjects with mild to severe TBI and in 10 control subjects without TBI.[75]

Interpretability

Norms: The documentation and software from NeuroCom provides comparison to normative data for subjects in the age ranges of 20 to 59, 60 to 69, and 70 to 79. Wrisley et al studied the learning effects of the equilibrium scores on SOT conditions in 13 healthy subjects (6 men, 7 women) between the ages of 21 and 36 years (mean age 24 +/− 4 years) to determine clinically meaningful change scores for the SOT. Subjects were tested five times over a 2-week period, with a retention test 1 month later. The first three conditions did not demonstrate a learning effect, while the increase in scores for conditions 4, 5, and 6 plateaued after the third session. Therefore, data for the fourth trial is an example of normative values in the young, healthy population (composite score: 89.2 ± 2.1):

1. eyes open, firm surface (%): 95.8 ± 0.8
2. eyes closed, firm surface (%): 93.0 ± 1.9
3. sway reference vision, firm surface (%): 93.6 ± 2.0
4. eyes open, sway reference surface (%): 92.8 ± 1.9
5. eyes closed, sway reference surface (%): 83.6 ± 3.1
6. sway reference vision and surface (%): 82.8 ± 5.6[76]

MDC: A learning effect has been demonstrated in healthy young adults. An improvement of greater than 8 points on the composite score "would be considered a change greater than the learning of the task."[76] In a study to assess sensitivity and specificity of the CDP and SOT variables, Broglio et al, using the reliable change index, developed cut scores for each SOT variable using a range of confidence intervals from 70% to 95%.[77(p150)] This work involved NeuroCom SOT assessments completed

TABLE 3-6

RELIABLE CHANGE AND CUT SCORES FOR SOT VARIABLES IN HEALTHY AND CONCUSSED YOUNG ADULTS

Change Scores	RCI Value	Composite Balance	Somatosensory Ratio	Visual Ratio	Vestibular Ratio
95% CI	1.96	9.75	10.08	11.93	25.69
90% CI	1.65	8.48	8.46	9.99	22.41

CI: confidence interval
RCI: reliable change index
SOT: Sensory Organization Test
Data source: Broglio SP, Ferrara MS, Sopiarz K, Kelly MS. Reliable change of the sensory organization test. *Clin J Sport Med*. Mar 2008;18(2):148–154.

twice on 66 healthy (age 20.1 +/− 1.96 years) and 63 concussed (age 20.3 +/− 1.35 years) young adults. Findings for the 90% and 95% confidence interval cut scores are found in Table 3-6.

Responsiveness Estimates: Data could not be located for persons with c/mTBI.

Sensitivity and Specificity

Broglio et al found the highest sensitivity (57%) and specificity (80%) at the 75% confidence interval using estimates of reliable change on the Neuro-Com SOT to distinguish between healthy (n = 66) and concussed (n = 63) young adults.[77] DiFabio completed a metaanalysis of the sensitivity and specificity of platform posturography and found an overall sensitivity and specificity of about 50%.[78] Individual diagnostic categories were found to influence the predictive value of abnormal results (73% for benign paroxysmal positional vertigo and Ménèiere disease, and 41% for peripheral vestibular disease).[78]

In a review of the literature by DiFabio,[79] dynamic posturography (SOT and MCT) were found to be highly specific for detecting vestibular dysfunction (specificity over 90%). The sensitivity of either static or dynamic posturography was low, but improved to 61% to 89% in detecting vestibular deficits if combined with tests of horizontal vestibulo-ocular reflex function.[79]

Reliability Estimates

- Test-Retest:
  - SOT: In 13 healthy adults (ages 21 to 36), composite SOT score was 0.67 (ICC [2,3]) when tested an average of 1.7 days apart. According to Wrisley et al, individual equilibrium scores for all conditions except condition 3 (stable surface, sway referenced vision) were also fair to good, with scores ranging from 0.43 to 0.79 from session 1 to session 2. Condition 3 showed poor test-retest reliability with an ICC (2,3) of 0.35.[76]
    Test-retest reliability in 66 healthy participants (39 men, 27 women, ages 20.1+/−1.96 years) tested an average of 49.1 days apart resulted in a composite balance of r = 0.56, somatosensory ratio of r = 0.10, visual ratio of r = 0.27, and vestibular ratio of r = 0.51.[77]
  - MCT: not available in healthy young adults or those with c/mTBI. In a study of 98 middle-aged and elderly adults, latency and response strength measures of the MCT showed good test-retest reliability (ICCs 0.66–0.98).[80] Procedures for manually marked latencies must be consistently established within clinics.[81]

Validity Estimates

- Content/Face: SOT and MCT test the sensory systems that contribute to balance and postural reactions to external perturbations that allow balance recovery.
- Criterion: CDP discriminated between patients with dizziness (n = 37) and normal controls (n = 22) with dizzy patients classified by audiometry, bithermal calorics, electronystagmography, tympanography, and rotational chair testing.
- Construct: NeuroCom has documented validity in multiple populations, such as vestibular injury, Parkinson's disease,

and multiple sclerosis. SOT scores of college athletes suffering mild head injuries showed significant deficits lasting 3 to 7 days when all other tests were normal and when compared to their preinjury baselines.[82] The concussion group had reductions in SOT scores over the first week, while neuropsychological tests were normal.

Postural stability deficits outlasted most neuropsychological and self-report symptoms in 24 subjects with sport-related concussion versus normal control subjects.[83] A systematic review of the published literature on the evidence of validity, reliability, and responsiveness of CDP measurements systems used in rehabilitation found that most of the studies were of poor design, making clinically meaningful decisions based on CDP findings difficult.[84]

Selected Reference

Balance Manager Systems, Clinical Interpretation Guide. NeuroCom International, Inc: Clackamas, OR: 2008.

HIGH-LEVEL MOBILITY ASSESSMENT TOOL

Purpose/Description

The HiMAT is a physical performance test used to assess high-level mobility deficits following TBI and to quantify therapy outcomes following intervention (Figure 3-1).[85,86]

Recommended Instrument Use

This test, which includes activities such as running and jumping, may be considered to assess higher-level mobility prior to using the service-specific fitness tests or obstacle courses. Note that it has not yet been specifically tested on persons with c/mTBI only, and there may be a ceiling effect given the normative value findings for males.[87]

Administration Protocol/Equipment/Time

The HiMAT consists of 13 items that are measured using either a stopwatch or tape measure. Measures obtained on each item are scored on a 0-to-5 scale based on time or distance and summed for a total HiMAT score (maximum score 54). Higher scores indicate better mobility performance. Depending on the client's ability and how many items he or she can perform, testing takes 5 to 15 minutes. No formal training is required to administer the HiMAT.

Groups Tested With This Measure

In one study, 103 ambulatory persons with TBI, recruited from inpatients, outpatients, and annual review clinics, were evaluated using HiMAT.[85,86] In another, 103 young, healthy adults ages 18 to 25 years old were tested, as were 28 people with chronic acquired brain injury undergoing a 3-month, high-level mobility program of strengthening exercises, prerunning and running drills,

and agility exercises supplemented with a gym or home exercise program.[87] The HiMAT is available on the Internet (www.tbims.org/combi/list.html).

Interpretability

- Norms: 103 young, healthy adults ages 18 to 25.[87] The median HiMAT score in males was 54/54 (interquartile range 53–54), and the 5th percentile was 50. A ceiling effect was evident for males, as 52.1% achieved the maximum score. The median HiMAT score in females was 51/54 (interquartile range 48–53), and the 5th percentile was 44.
- MDC: MDC_{95} +/− 2.66 points. If the patient's score is less than the MDC value, it is considered indistinguishable from measurement error. Given test and retest mean difference (1 point) to be 95% confident that clinically important change has occurred, persons have to improve by 4 points or deteriorate by at least 2 points.[88]

Responsiveness Estimates

Fourteen persons with TBI were initially tested less than 12 months after injury and were tested again 3 months later. These subjects were still considered to be in the acute recovery phase and were expected to improve over the 3-month interval. The individuals improved an average of 12.1 points (range 3–25 points) on the HiMAT.[89]

Reliability Estimates

- Internal consistency: Chronbach's alpha of 0.99 indicating that the extent to which the items measure the same domain was very high.

HiMAT: HIGH-LEVEL MOBILITY ASSESSMENT TOOL

DATE.....................

DATE OF ACCIDENT.....................

DIAGNOSIS.....................

AFFECTED SIDE   LEFT/RIGHT

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		SCORE					
ITEM	PERFORMANCE	0	1	2	3	4	5
WALK	sec	X	> 6.6	5.4–6.6	4.3–5.3	< 4.3	X
WALK BACKWARD	sec		> 13.3	8.1–13.3	5.8-8.0	< 5.8	X
WALK ON TOES	sec		> 8.9	7.0–8.9	5.4–6.9	< 5.4	X
WALK OVER OBSTACLE	sec		> 7.1	5.4–7.1	4.5–5.3	< 4.5	X
RUN	sec		> 2.7	2.0–2.7	1.7–1.9	< 1.7	X
SKIP	sec		> 4.0	3.5–4.0	3.0–3.4	< 3.0	X
HOP FORWARD (AFFECTED)	sec		> 7.0	5.3–7.0	4.1–5.2	< 4.1	X
BOUND (AFFECTED)	1) _____ cm 2) _____ cm 3) _____ cm		< 80	80–103	104–132	> 132	X
BOUND (LESS AFFECTED)	1) _____ cm 2) _____ cm 3) _____ cm		< 82	82–105	106–129	> 129	X
UP STAIRS	sec		> 22.8	14.6–22.8	12.3–14.5	< 12.3	X

Figure 3-1. High-Level Mobility Assessment Tool (continued on next page)

		sec						
DEPENDENT (Rail **OR** not reciprocal; if not, score 5 and rate below)								
UP STAIRS INDEPENDENT (No rail **AND** reciprocal; if not, score 0 and rate above)	sec		> 9.1	7.6–9.1	6.8–7.5	< 6.8	X
DOWN STAIRS DEPENDENT (Rail **OR** not reciprocal; if not, score 5 and rate below)	sec		> 24.3	17.6–24.3	12.8–17.5	< 12.8	X
DOWN STAIRS INDEPENDENT (No rail **AND** reciprocal; if not, score 0 and rate above)	sec		> 8.4	6.6–8.4	5.8–6.5	< 5.8	X
	SUBTOTAL						

TOTAL HiMAT SCORE **/54**

Figure 3-1. (continued on next page)

HiMAT: High-Level Mobility Assessment Tool

Subject suitability:	The HiMAT is appropriate for assessing people with high-level balance and mobility problems. The minimal mobility requirement for testing is independent walking over 20 m without gait aids. Orthoses are permitted.
Item testing:	Testing takes 5–10 minutes. Patients are allowed 1 practice trial for each item.
Instructions:	Patients are instructed to perform at their maximum safe speed except for the bounding and stair items.
Walking:	The middle 10 m of 20-m trial is timed.
Walk backward:	As for walking.
Walk on toes:	As for walking. Any heel contact during the middle 10 m is recorded as a fail.
Walk over obstacle:	As for walking. A house brick is placed across the walkway at the midpoint. Patients must step over the brick without contacting it. A fail is recorded if patients step around the brick or make contact with the brick.
Run:	The middle 10 m of a 20-m trial is timed. A fail is recorded if patients fail to have a consistent flight phase during the trial.
Skipping:	The middle 10 m of a 20-m trial is timed. A fail is recorded if patients fail to have a consistent flight phase during the trial.
Hop forward:	Patients stand on their more affected leg and hop forward. The time to hop 10 m is recorded.
Bound (affected):	A bound is a jump from one leg to the other with a flight phase. Patients stand behind a line on their less affected leg, hands on hips, and jump forward **landing on their more affected leg**. Each bound is measured from the line to the heel of the landing leg. The average of three trials is recorded.
Bound (less affected):	Patients stand behind a line on their more affected leg, hands on hips, and jump forward **landing on their less affected leg**. The average of three trials is recorded.
Up stairs:	Patients are asked to walk up a flight of 14 stairs as they normally would and at their normal

Figure 3-1. (continued on next page)

speed. The trial is recorded from when the patient starts until both feet are at the top. Patients who

use a rail or nonreciprocal pattern are scored on **Up Stairs Dependent**. Patients who ascend the

stairs reciprocally without a rail are scored on **Up Stairs Independent** and get an additional 5

points in the last column of Up Stairs Dependent.

Down stairs: As for Up stairs.

Scoring: All times and distances are recorded in the "performance" column. The corresponding score for

each item is then circled and each column is then subtotaled. Subtotals are then added to

calculate the HiMAT score.

Figure 3-1. High-Level Mobility Assessment Tool (HiMAT) and instructions.
Reproduced with permission from Gavin Williams. Please notify Gavin Williams at gavin.williams@epworth.org.au
or gavin@neuro-solutions.net so the use of the HiMAT can be tracked.

- Interrater: Three experienced physical therapists (two of whom had no prior knowledge of the HiMAT) concurrently and independently scored performances of 17 persons with TBI.[86]
  - ICC (2,1) = 0.99 for individual items.
  - ICC (2,1) = 0.99 for total scores.
- Intrarater: Twenty people with TBI occurring at least 18 months prior to testing were retested 2 days after their initial test. The retest ICC (2,1) was 0.99.[88]
- Test-Retest: The mean difference between test and retest 2 days later was 1 point. Standard error of measurement (SEM) was calculated to determine the 95% confidence interval for determining MDC. MDC was calculated to be +/− 2.66 points, indicating 95% confidence that clinically important change has occurred if individuals have improved by 4 points or deteriorated by at least 2 points.[88]

Validity Estimates

- Content/Face: Content was initially generated from a review of existing mobility scales and by surveys of experts.[85]

- Criterion: 103 persons with TBI were concurrently scored on the HiMAT, motor Functional Independence Measure (FIM), and gross function Rivermead Motor Assessment (RMA). Correlations (using Pearson r) were calculated between the HiMAT, the motor FIM, and the gross function component of the RMA to investigate concurrent validity. The correlation between the HiMAT and the motor FIM was only moderately strong (r = 0.53, P < 0.01) due to a substantial ceiling effect the motor FIM suffers when compared to the HiMAT. More specifically, the motor FIM was unable to discriminate motor performance for 90 (87.4%) of the 103 patients, yet these patients had a mean score on the HiMAT of only 32.6/54 (SD 13.8, range 5–54).[89] The HiMAT and gross function RMA had a much stronger correlation (r = 0.87, P < 0.01), but the gross function RMA also had a substantial ceiling effect when compared to the HiMAT. Of the 103 subjects, 53 (51.5%) scored the maximum score of 13/13 on the gross function RMA, yet had a mean score of only 41.7/54 on the HiMAT (SD 8.8, range 24–54).[89]
- Construct: not available

Selected References

Williams G, Robertson V, Greenwood K, Goldie P, Morris ME. The High-level Mobility Assessment Tool (HiMAT) for traumatic brain injury. Part 1: Item generation. *Brain Inj*. 2005;19(11):925–932.

Williams G, Robertson V, Greenwood K, Goldie P, Morris ME. The High-level Mobility Assessment Tool (HiMAT) for traumatic brain injury. Part 2: Content validity and discriminability. *Brain Inj*. 2005;19(10):833–843.

REVISED HIGH-LEVEL MOBILITY ASSESSMENT TOOL

The revised HiMAT is a modification of the original HiMAT (Figure 3-2). Rausch analysis was used to delete items and develop a unidimensional measure of "high-level mobility limitations" in persons with TBI.[90] This revised test no longer requires stairs.

Recommended Instrument Use

With test items such as running and jumping, this test may be considered for use to assess higher-level mobility prior to using the service-specific fitness tests or obstacle courses. It has not yet been specifically tested on persons with c/mTBI only, and there may be a ceiling effect given the normative value findings for males.[91] It may be considered for use in clinics or deployed settings where no stairs are available.

Administration Protocol/Equipment/Time

The revised HiMAT consists of eight items measured using either a stopwatch (to 1/10th second) or tape measure (in centimeters); a house brick is required as an obstacle. Measures obtained on each item are scored on a 0-to-4 scale based on time or distance and summed for a total HiMAT score (maximum score is 32). Higher scores indicate better mobility performance. Depending on the client's ability and how many items he or she can perform, testing takes 5 to 10 minutes; 1 practice trial is given for each item. No formal training is required to administer the HiMAT.

Groups Tested With This Measure

Data was reanalyzed for the original 103 ambulatory persons with primarily moderate and severe TBI recruited from inpatients, outpatients, and annual review clinics.[85,86,90]

Interpretability

- Norms: The original HiMAT tested 103 young, healthy adults ages 18 to 25.[91] Given that males demonstrated a ceiling effect and the interquartile range of 53 to 54, the norms for healthy, 18- to 25-year-old males would be expected to be 32 (see information for the full HiMAT[91]). Females were

not retested for the revised HiMAT; see information on normative values for the full HiMAT.[91]
- MDC: MDC_{95} +/– 2 points. If the patient's score is less than the MDC value, it is considered indistinguishable from measurement error.

Responsiveness Estimates: not specifically retested for the revised HiMAT; see information on the full HiMAT.

Reliability Estimates

- Internal consistency: Revised HiMAT showed excellent internal consistency for high-level mobility (Pearson separation index = 0.96).[87] The information on rater reliability and retest reliability are from the original HiMAT, as the original dataset was reanalyzed.
- Interrater: Three experienced physical therapists (two of whom had no prior knowledge of the HiMAT) concurrently and independently scored performances of 17 persons with TBI.[88]
  - ICC (2,1) = 0.99 for individual items
  - ICC (2,1) = 0.99 for total scores
- Intrarater: Twenty people with TBI occurring at least 18 months prior to testing were retested 2 days after the initial test. The retest ICC (2,1) was 0.99.[88]
- Test-Retest: The mean difference between test and retest 2 days later was 1 point. SEM was calculated to determine the 95% confidence interval for determining MDC. MDC was calculated to be +/– 2.66 points, indicating 95% confidence that clinically important change has occurred if individuals have improved by 4 points or deteriorated by at least 2 points.[88]

Validity Estimates

- Content/Face: Content was initially generated from a review of existing mobility scales and by surveys of experts.[85]
- Criterion: See information under the original HiMAT; testing has not been redone using the revised HiMAT.
- Construct: not available

REVISED HiMAT (NO STAIR ITEMS)

DATE.....................

DATE OF ACCIDENT.....................

DIAGNOSIS.....................

AFFECTED SIDE   LEFT/RIGHT

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PATIENT ID LABEL

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ITEM	PERFORMANCE		0	1	2	3	4
WALK		sec	X	> 6.6	5.4–6.6	4.3–5.3	< 4.3
WALK BACKWARD		sec		> 13.3	8.1–13.3	5.8-8.0	< 5.8
WALK ON TOES		sec		> 8.9	7.0–8.9	5.4–6.9	< 5.4
WALK OVER OBSTACLE		sec		> 7.1	5.4–7.1	4.5–5.3	< 4.5
RUN		sec		> 2.7	2.0–2.7	1.7–1.9	< 1.7
SKIP		sec		> 4.0	3.5–4.0	3.0–3.4	< 3.0
HOP FORWARD (AFFECTED)		sec		> 7.0	5.3–7.0	4.1–5.2	< 4.1
BOUND (LESS AFFECTED)	1) cm 2) cm 3) cm			< 82	82–105	106–129	> 129
	SUBTOTAL						

*Note: When using the Revised HiMAT, the MDC score is +/– 2 points. This means that a 2-point score change is required to be 95% confident that true change has occurred.

TOTAL HiMAT SCORE   **/32**

Figure 3-2. Revised High-Level Mobility Assessment Tool (continued on next page)

HiMAT: High-Level Mobility Assessment Tool

Subject suitability:	The HiMAT is appropriate for assessing people with high-level balance and mobility problems. The minimal mobility requirement for testing is independent walking over 20 m without gait aids. Orthoses are permitted.
Item testing:	Testing takes 5–10 minutes. Patients are allowed 1 practice trial for each item.
Instructions:	Patients are instructed to perform at their maximum safe speed except for the bounding and stair items.
Walking:	The middle 10 m of 20-m trial is timed.
Walk backward:	As for walking.
Walk on toes:	As for walking. Any heel contact during the middle 10 m is recorded as a fail.
Walk over obstacle:	As for walking. A house brick is placed across the walkway at the midpoint. Patients must step over the brick without contacting it. A fail is recorded if patients step around the brick or make contact with the brick.
Run:	The middle 10 m of a 20-m trial is timed. A fail is recorded if patients fail to have a consistent flight phase during the trial.
Skipping:	The middle 10 m of a 20-m trial is timed. A fail is recorded if patients fail to have a consistent flight phase during the trial.
Hop forward:	Patients stand on their more affected leg and hop forward. The time to hop 10 m is recorded.
Bound (less affected):	A bound is a jump from one leg to the other with a flight phase. Patients stand behind a line on their more affected leg, hands on hips, and jump forward **landing on their less affected leg**. The average of three trials is recorded.
Scoring:	All times and distances are recorded in the "performance" column. The corresponding score for each item is then circled and each column is then subtotaled. Subtotals are then added to calculate the HiMAT score.

Figure 3-2. Revised High-Level Mobility Assessment Tool (HiMAT; no stairs) and instructions.

Selected Reference

Williams G, Pallant J, Greenwood K. Further development of the High-level Mobility Assessment Tool (HiMAT). *Brain Inj*. 2010;24(7–8):1027–1031.

GAIT SPEED

Purpose/Description

Gait speed is a physical performance test derived directly from measuring the parameters of distance and time. It has been used as a gold standard to validate outcome measures in various patient populations.

Recommended Instrument Use

Gait speed is a standard measure that should be used for all ambulatory patients. It has been proposed as a sixth vital sign.[6]

Administration Protocol/Equipment/Time

Testing takes less than 5 minutes, depending on the number of trials and speeds tested. Equipment includes a stopwatch that can record to tenths of a second, a tape measure, and a level surface of at least 9.1 meters (30 ft). Shoes are recommended and the use of a subject's habitual assistive device is permitted and indicated.

Groups Tested With This Measure

Gait speed testing has been used to assess the following individuals:

- those who have sustained stroke,[92]
- those with multiple sclerosis,[93]
- healthy adults,[94]
- amputees,
- those with rheumatoid arthritis,
- children with traumatic brain injury,[95-97]
- individuals with osteoarthritis,
- the elderly,
- those who have sustained spinal cord injury,
- individuals with Parkinson's disease,[38] and
- individuals with cerebral palsy.[98]

Interpretability

Norms: Tables 3-7–3-9[99]

MDC: In 37 community-dwelling adults with Parkinsonism, MCD (95%)was 0.18 m/s for comfortable gait speed, and 0.25 m/s for fast gait speed.[38] Steffen and Seney[38] summarize the literature on test-retest reliability in stroke and TBI and report MDC (95%) values of 0.11 to 0.24 m/s for comfortable gait speed and 0.24 m/s for fast gait speed. MDC values could not be found for persons with c/mTBI. If the patient's score is less than the MDC value, it is considered indistinguishable from measurement error (Table 3-10).

TABLE 3-7

GAIT SPEED (MEN)[*]

Age	N	Comfortable Pace			Fast Pace		
		cm/s	m/s	ft/s	cm/s	m/s	ft/s
20	15	139.3	1.393	4.57	253.3	2.533	8.31
30	13	145.8	1.458	4.78	245.6	2.456	8.06
40	22	146.2	1.462	4.80	246.2	2.462	8.08
50	22	139.3	1.393	4.57	206.9	2.069	6.79
60	18	135.9	1.359	4.46	193.3	1.933	6.34
70	22	133.0	1.330	4.36	207.9	2.079	6.82

[*]See data source for height normalized gait speed factor for each age group.
Data source: Bohannon RW. Comfortable and maximum walking speed of adults aged 20–79 years: reference values and determinants. *Age and Ageing* 1997;26:15–19. Table 4.

TABLE 3-8

GAIT SPEED (WOMEN)[*]

Age	N	Comfortable Pace			Fast Pace		
		cm/s	m/s	ft/s	cm/s	m/s	ft/s
20	22	140.7	1.407	4.61	246.7	2.467	8.09
30	23	141.5	1.415	4.64	234.2	2.342	7.68
40	21	139.1	1.391	4.56	212.3	2.123	6.96
50	21	139.5	1.395	4.58	201.0	2.010	6.59
60	18	129.6	1.296	4.25	177.4	1.774	5.82
70	20	127.2	1.272	4.17	174.9	1.749	5.74

[*]See data source for height normalized gait speed factor for each age group.
Data source: Bohannon RW. Comfortable and maximum walking speed of adults aged 20–79 years: reference values and determinants. *Age and Ageing* 1997;26:15–19. Table 4.

TABLE 3-9

GAIT SPEED IN SINGLE TASK AND DUAL TASK CONDITIONS IN YOUNG ADULTS

Group (N = 14 in all groups)	Day 2 (m/s) Single Task	Day 2 (m/s) Dual Task
Concussed Athletes	1.227 ± 0.150	1.101 ± 0.174
Concussed Nonathlete	1.270 ± 1.127	1.321 ± 0.114
Normal Athlete	1.217 ± 0.134	1.196 ± 0.152
Normal Nonathlete	1.381 ± 0.107	1.391 ± 0.142

Data source: Parker TM, Osternig LR, van Donkelaar P, Chou LS. Balance control during gait in athletes and non-athletes following concussion. *Med Eng Phys.* Oct 2008;30(8):959–967.

Responsiveness Estimates

- Functional walking categories[92]
  - physiologic walker: 0.1 m/s
  - limited household walker: 0.23 m/s
  - unlimited household walker: 0.27 m/s
  - most limited household walker: 0.4 m/s
  - least limited household walker: 0.58 m/s
  - community walker: 0.8 m/s

Reliability Estimates

- Internal consistency: not applicable
- Interrater: In a group of 12 ambulatory subjects an average of 15.8 months after TBI (initial mean Glasgow Come Scale score of 5.8), interrater reliability (IRR) of five trials of comfortably paced walking speed was 0.99, and IRR of fast-paced walking speed was 0.99. In persons with stroke, r = 1.0.[100]
- Intrarater: not available
- Test-Retest: comfortable walking speed ICC (3,1) = 0.903. Fast walking speed ICC (3,1) = 0.910 (adults)[101]

Validity Estimates

- Content/Face: not applicable

TABLE 3-10

MINIMAL DETECTABLE CHANGE IN GAIT SPEED FOR MEN AND WOMEN IN THEIR 20S DURING COMFORTABLE AND FAST WALKING

MDC 90%	Comfortable m/s	Comfortable ft/s	Fast m/s	Fast ft/s
Men	0.11	0.36	0.20	0.67
Women	0.13	0.41	0.18	0.60

Data source: Bohannon RW. Comfortable and maximum walking speed of adults aged 20–79 years: reference values and determinants. *Age Ageing.* 1997;26(1):15–19.

- Criterion: In a group of 12 ambulatory subjects, an average of 15.8 months after TBI (initial mean Glasgow Come Scale score of 5.8), correlation of a stopwatch measure over a known distance to measurement with infrared timing gates indicated a perfect concurrent validity.[96]
- Construct: Age, height, and hip, knee, and ankle muscle strength correlated significantly (P < 0.05) with both comfortable and maximum gait speed. Gender correlated significantly with maximum gait speed. Leisure activity and work activity were not significantly correlated with either comfortable or maximum gait speed.[101]
- Within the first 48 hours following concussion, gait velocity was found to be significantly slower in concussed subjects than in normal subjects in both single- and dual-task conditions.[102]
- Following TBI, 10 subjects (4 with mild TBI, with GCS scores greater than 12, 9 subjects evaluated within 2 years after their injury) walked with a significantly slower gait speed (1.15 +/− .17 m/s) than 10 age-, gender-, height-, and weight-matched controls (1.31 +/− 1.1).[103]

Selected References

van Loo MA, Moseley AM, Bossman JM, de Bie RA, Hassett L. Inter-rater reliability and concurrent validity of walking speed measurement after traumatic brain injury. *Clinical Rehab*. 2003;17:775–779.

van Loo MA, Moseley AM, Bossman JM, de Bie RA, Hassett L. Test-retest reliability of walking speed, step length and step width measurement after traumatic brain injury: a pilot study. *Brain Inj*. 2004;18(10):1041–1048.

GAIT SPEED

General Instructions

- Mark off a 20-ft (6.1-m) unobstructed walk-way on the floor with colored tape.
- Mark an additional 5 ft (0.91 m) from the start and end of the walkway (total 30 ft) for acceleration and deceleration and place a cone, pylon, or other marker at the finish line (before the 5-ft deceleration zone).
- Start the subject at the beginning of the acceleration zone. Begin timing when the subject's first foot crosses the start line marker. Stop timing when the subject's first foot crosses the finish line marker.
- Record the time to the tenths of a second. Record the faster of two trials.
- Gait speed is measured in distance walked in a given time (gait speed = distance/time; eg, 20 ft/4.1 seconds = 4.88 ft/sec = 1.49 m/sec), typically measured in meters per second or feet per second.
- The time in distance (meters or feet) is divided by the number of seconds recorded (Exhibit 3-6).
- Therapist should walk next to the subject and use a gait belt if there are any safety concerns.

Standardized Instructions to Give at the Start Line

- *Walk at a comfortable walking speed to the cone at the end of the walkway.*
- *Walk as fast as you can safely walk to the cone at the end of the walkway.*

Note: If space considerations warrant, any standard distance can be used with markers at the start and finish line and 3 to 5 feet before and after the lines for acceleration and deceleration. Gait speed is usually reported in meters per second but can be reported in feet per second as long as the comparisons are consistent.

EXHIBIT 3-6

GAIT SPEED RECORDING

Comfortable Speed:
Trial 1 _____ seconds   Trial 2 _____ seconds
Fast Speed:
Trial 1 _____ seconds   Trial 2 _____ seconds

FUNCTIONAL GAIT ASSESSMENT

The FGA is a ten-item gait assessment based on the Dynamic Gait Index (DGI) developed to avoid the ceiling effect of the DGI in persons with vestibular disorders. Items added to the DGI were gait with narrow base of support, ambulating backwards, and gait with eyes closed.[8] The maximum FGA total score is 30, with each item measured on a 0-to-3 scale (Exhibit 3-7).

Recommended Instrument Use

A standardized measure of gait ability is recommended. Options include the FGA in addition to a measure of gait speed.

Administration Protocol/Equipment/Time

The FGA takes approximately 20 minutes and requires a marked, 20-ft (6-m) walkway with a marked 12-inch (30.48-cm) width.

Groups Tested With This Measure

Groups tested with this measure include 6patients with vestibular disorders[8]; 200 adults, ages 40 to 89 years, living independently[104]; 35 subjects with balance deficits (mean age 66.6 with SD 13.9) and 39 control subjects (mean age of 32.2 with SD 15.1)[105]; and 35 older adults aged 60 to 90 years.[106]

Interpretability

- Norms: See Table 3-11. In a comparison of the FGA and the SOT for 39 control subjects (nonfallers) with mean age of 32.2 (SD 15.1), the mean FGA score was 24.8 (SD 4.6), with a 95% confidence interval of 23.6 to 26.1[105]
- MDC: not available. If the patient's score is less than the MDC value, it is considered indistinguishable from measurement error.

EXHIBIT 3-7

ADDITIONAL RESOURCES FOR FUNCTIONAL GAIT ASSESSMENT

This instrument can be obtained from the original publication:

Wrisley DM, Marchetti GF, Kuharsky DK, Whitney SL. Reliability, internal consistency and validity of data obtained with the Functional Gait Assessment. *Phys Ther*. 2004;84:906–918.

It can be found through links at the following websites:

- Rehabilitation Measures Database www.rehabmeasures.org/rehabweb/allmeasures.aspx?PageView=Shared
- Geriatric Examination Toolkit (University of Missouri) web.missouri.edu/~proste/tool/vest/index.htm

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Responsiveness Estimates: not available

Reliability Estimates (tested with experienced and student therapists)

- Internal consistency: Chronbach's alpha = 0.79 across two trials. Item-to-corrected-item correlations ranged from 0.12 to 0.80.[8]
- Interrater
  - Total score: ICC = 0.84
  - Percent agreement:0 58%
  - Individual items: 40%–90%
  - Kappa: 0.50
  - Individual items 0.16–0.83[8] This study involved raters who were not trained on the FGA.
  - ICC (model 2) = 0.93 for 200 adults, ages 40–89 years old, living independently.[104] This study involved raters who were trained on the FGA.
- Intrarater
  - Total score: ICC = 0.83
  - Percent agreement: 67%
  - Individual items: 60%–90%
  - Kappa: 0.50
  - Individual items: 0.37–0.78 (raters were not trained on the FGA)[8]
- Test-Retest: not available

Validity Estimates

- Content/Face: FGA is based on the DGI, which was developed to assess postural stability during gait tasks in older adults at risk of falling. Because of the ceiling effect of the DGI in younger patients with vestibular disorders who still report gait difficulties, the FGA was constructed as a modified version of the DGI with one item removed and three items added.[8]
- Criterion: FGA scores were correlated with the ABC Scale scores (r = 0.64), DHI scores (r = –0.64), perception of dizziness symptoms on a Visual Analog Scale (r = – 0.70), number of falls (r = – 0.66), Timed Up and Go scores (r = 0.50), and DGI scores (r = 0.80).[104]
  FGA scores demonstrated high correlation with the SOT (r = 0.713), high negative correlation between the FGA and age (r = – 0.786), and moderate negative correlation between the FGA and fall history (r = – 0.573) in 35 subjects with balance deficits (mean age 66.6 with SD 13.9) and 39 control subjects (mean age of 32.2 with SD 15.1).[105]
  In 35 older adults aged 60 to 90 years, the FGA correlated with the ABC Scale (r = 0.053), Berg Balance Scale (r = 0.84), and Timed Up and Go Test (r = – 0.84).[106]
- Construct: Mean total scores for the FGA show a systematic decrease with increased age, especially in subjects aged 70 years and older.[104] According to Wrisley and Kumar, the "FGA (scores 22/30) provided 100% sensitivity, 72% specificity, positive likelihood ratio of 3.6, and negative likelihood ratio of 0 to predict prospective falls."[106]

TABLE 3-11

FUNCTIONAL GAIT ASSESSMENT TOTAL SCORES BY DECADE

Age (y)	N	Minimum Score	Maximum Score	Mean	Standard Deviation	95% Confidence Interval
40–49	27	24	30	28.9	1.5	28.3–29.5
50–59	33	25	30	28.4	1.6	27.9–29.0
60–69	63	20	30	27.1	2.3	26.5–27.7
70–79	44	16	30	24.9	3.6	23.9–26.0
80–89	33	10	28	20.8	4.7	19.2–22.6
Total	**200**	**10**	**30**	**26.2**	**4.0**	**25.5–26.6**

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ILLINOIS AGILITY TEST

Purpose/Description

The IAT requires a person to run short distances while navigating obstacles; it involves speeded cutting and direction changes.[9]

Recommended Instrument Use

A standardized measure of agility that was developed for physical fitness testing in healthy populations, this test is relevant for service members because it tests high-level mobility on a course that requires maneuvering with fast directional changes.

Administration Protocol/Equipment/Time

The IAT takes approximately 5 minutes to administer. It requires a flat, nonslip surface, stopwatch, eight cones, and a measuring tape to set up the course. The course is 10 m in length by 5 m in width. Four cones mark the corners of the perimeter of the course: the start line is marked by two cones on one end, and the turning line is marked by two cones on the opposite side of the 10-m length. The additional four cones are positioned equidistant (3.3 m apart) along the center of the 10-m length at the 2.5-m mark.

A "jog-through" of the course and the pattern that is traversed is necessary prior to timed testing. Use Figure 3-3 to set up the course and to instruct service members in the expected pattern. Initial testing protocol requires the service member to start positioned at the left of the starting line in a push-up position, with the vertex of the head in line with the starting line (position A). When given the "go" signal, the service member stands and runs to touch the base of the cone on the far left of the course (position B), then returns to the center cone that is closest to the starting line, proceeding in a serpentine pattern around each of the four cones in the center of the course. At the fourth cone, the service member continues the serpentine pattern back to the first cone near the start line. After rounding that cone for the second time, the service member runs quickly to the cone on the far right of the course (position C), touches the base of it, and returns to the starting line as quickly as possible (position D). Starting position may be modified to standing; however, norms would no longer apply. If the required-size space is not available in a clinical environment, a smaller course could be created; however, norms would not be translatable to a different course.

The test is administered twice and the fastest of the two times is recorded.

Groups Tested With This Measure

Details of data gathered to establish norms are unpublished, but are presumed to include healthy, active college students from a textbook by Getchell.[9] These values are reproduced in numerous other sources.[107,108] Additional studies have focused on elite soccer athletes,[109] law enforcement officers,[110] and US Army Soldiers who were active and healthy.[111] This group also studied service members with transtibial and transfemoral amputation.[112]

Interpretability

- Norms: Mean IAT time for a group of active duty service members (97 male soldiers, mean age 26.2 years, mean number of physical training days per week 5.0) was 18.17 seconds (SD 1.14 s).[111] Law enforcement officer standards[110] suggest a police academy entrance standard of 22.3 seconds, requiring scores of 18.6 on average for men and 20.2 seconds for women to meet performance standards following training. FitForce Guidelines[113] suggest median scores for federal and municipal agencies at 18.1 to 18.2 seconds (Table 3-12).
- MDC: no data available

Responsiveness Estimates: no data available

Reliability Estimates

- Internal consistency: not available
- Interrater: ICC values for a battery of balance and fitness tests including the IAT ranged from 0.924 to 0.995 for healthy service members, and 0.97 to 0.99 for service members with amputation.[114]
- Intrarater: no data available
- Test-Retest: ICC values were higher for service members with amputation than for a healthy comparison group.[114] Serial tests for elite soccer athletes over the course of a season showed average scores varied slightly, but remained on average in the range of 14.63 to 14.97 seconds (SD 0.38 s).[109]

Validity Estimates

- Content/Face: The IAT is commonly used in athletic populations to assess speed and agility while running with direction changes and obstacle avoidance. The prone starting position has face validity: the ability to rapidly move from prone to running is similar to rapid transitions necessary in combat situations.
- Criterion: IAT performance times were highly correlated with times for two tests of agility, the T-test and the modified Edgren side-step test in a sample of 97 active duty, male, US Army soldiers (mean age 26.2 years, SD 5.5 years; mean number of
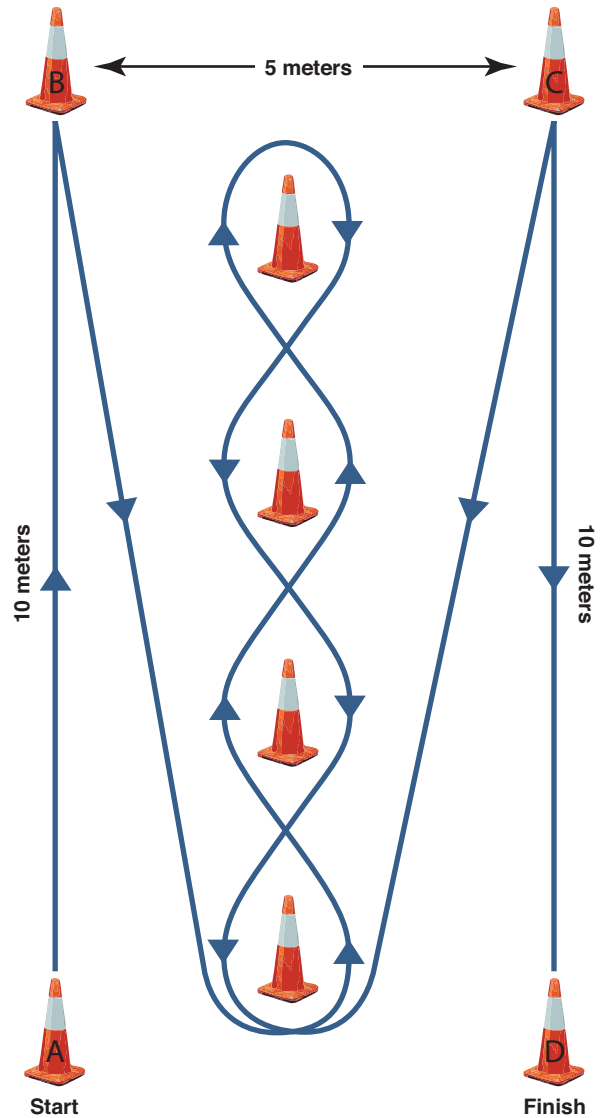
Figure 3-3. Illinois Agility Test. Service member to starts positioned at the left of the starting line in a push-up position, vertex of the head in line with the starting line (position A). When given the "go" signal, the service member stands and runs to touch the base of the cone on the far left of the course (position B), then returns to the center cone closest to the starting line, proceeding in a serpentine pattern around each of the four cones in the center of the course. At the fourth cone, the service member continues the serpentine pattern back to the first cone near the start line. After rounding that cone for the second time, the service member runs quickly to the cone on the far right of the course (position C), touches the base of it, and returns to the starting line as quickly as possible (position D). The test is administered twice and the fastest of the two times is recorded.

physical training days per week 5.0, SD .8 days; mean height 70.0 in., SD 2.5 in.; mean weight 181.4 lb, SD 23.2 lb).[111]

- Construct: Known groups comparison: a study of 97 active duty soldiers and 62 service members with amputation (42 with unilateral transtibial amputation, 20 with unilateral transfemoral amputation) performed three speed and agility tests. Analysis of variance showed significant group differences for active duty and amputee service members on the tests. Individuals with transtibial amputation performed better than those with transfemoral amputation, although 51% of the unilateral transtibial amputees performed within the range of values seen in the active duty control group. None of the transfemoral amputees completed tests in the active duty range.[112]

TABLE 3-12

TYPICAL ILLINOIS AGILITY TEST TIMES AND RATINGS[*]

Rating	Male	Female
Excellent	< 15.2	< 17.0
Good	16.1–15.2	17.9–17.0
Average	18.1–16.2	21.7–18.0
Fair	18.3–18.2	23.0–21.8
Poor	> 18.3	> 23.0

[*]This chart is available from multiple sources[1–3] but original data were not published, so specifics of test population age, size, and testing methods are not available. Clinicians using this test on a regular basis suggest the values for higher-level skill are rarely observed in practice, even with uninjured individuals. Therefore the accuracy of the ratings is debatable. Test results may be better interpreted as an evaluative measure for an individual gauging his or her improvement over time.
Data sources: 1) Getchell B. *Physical Fitness: A Way of Life*. 4th ed. 4th ed. New York, NY: Macmillan Publishing Company; 1992. 2) Roozen M. Illinois Agility Test. *National Strength and Conditioning Association's Performance Training Journal*. 2004;3(5):5–6. 3) Reiman MP, Manske RC. *Functional Testing in Human Performance*. Champaign, Il: Human Kinetics; 2009.

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Roozen M. Illinois Agility Test. *NCSA's Performance Training Journal*. 2004;3(5):3–5.

FIVE TIMES SIT-TO-STAND TEST

Purpose/Description

The Five Times Sit-To-Stand Test (FTSST) is a physical performance test initially developed to measure lower-extremity muscle strength.[3] It has also been used to examine functional status, balance, and vestibular dysfunction, and to distinguish between fallers and nonfallers.[115–119] Other versions include the Timed Stands Test and the Ten Chair Stands Test.

Recommended Instrument Use

The FTSST is a functional strength test option. Therapists should consider using it in addition to other strength screening tests.

Administration Protocol/Equipment/Time

Stopwatch and armless chair (height 43 cm, depth 47.5 cm) are required for the FTSST. The test takes less than 1 minute to administer. A practice trial can be given.

Groups Tested With This Measure

The FTSST has been used to test healthy males and females,[3] older adults,[119] and persons with balance deficits,[119] vestibular loss,[118] arthritis, renal disease,[120] and stroke.[115] The FTSST and other versions (Timed Stands, the Ten Times Sit-to-Stand Test) have been used as outcome measures after intervention.[119]

Interpretability

- Norms: 16 men and 16 women healthy normal subjects (age range 23-57 years) had a mean of 8.2 seconds (SD 0.3s), a range of 4.9 to 12.7 seconds, and a 95% CI of 7.5 to 8.8 seconds.[119]
  Using a time cutoff of 13 seconds, the FTSST identified subjects with balance dysfunction with a sensitivity (66%) and specificity (67%) in subjects 23 to 90 years old (both normal controls and subjects with balance dysfunction). For just those subjects less than 60 years old, the sensitivity (87%) and specificity (84%) was optimal at a cutoff point of 10 seconds.[119]
- MDC (95% CI): estimates vary depending on variability of test population. In 12 normal controls (adults ages 18–55 years

old), using a 90% confidence interval Blake and O'Meara (2004) found a MDC of 0.4 seconds.[120] In 30 older adults after hip fracture, using a 90% confidence interval Sherrington and Lord (2005) found a MDC of 6.7 seconds.[121] If the patient's score is less than the MDC value, it is considered indistinguishable from measurement error.

Responsiveness Estimates

One hundred and seventeen patients (45 men, 72 women), mean age 62.7 years, with peripheral, central, or mixed vestibular dysfunction underwent vestibular rehabilitation. Logistic regression showed that an improvement in the FTSST of greater than 2.3 seconds resulted in an odds ratio of 4.67 for demonstrating clinical improvement in DHI, compared to a change less than 2.3 seconds.[118] Subjects with central vestibular dysfunction (n = 12) showed an improvement of 6.8 seconds (+/− 6.3) in the FTSST from before to after rehabilitation.[122]

Reliability Estimates

- Internal consistency: not available
- Interrater: in individuals ages 60 and older ICC = 0.71 (n = 392)[123]
- Intrarater: in individuals ages 60 and older ICC = 0.64 (n = 392).[123] In 12 renal patients (ages 18–55 years old) and 12 age-matched controls, ICC = 0.98.[120]
- Test-Retest: ICC (3,1) = 0.92 (95% CI 0.84–0.97) for 27 inpatients and outpatients who had suffered a hip fracture.[121]

Validity Estimates

- Content/Face: The sit-to-stand task is a functional skill that requires lower-extremity strength.
- Criterion: For 72 subjects with balance or vestibular disorders and 81 control subjects (age range 23–90 years), the Spearman rho between the FTSST and DGI was –0.68 (P < 0.001), and between the FTSST and the ABC Scale was –0.58 (P < 0.001).[119]
- Construct: In 89 control- and balance-impaired subjects younger than 60 years old, the FTSST correctly identified subjects with balance disorders 81% of the time.[119]

Selected Reference

Csuka M, McCarty DJ. Simple method for measurement of lower extremity muscle strength. *Am J Med*. 1985;78:77–81.

FIVE TIMES SIT-TO-STAND TEST ADMINISTRATION

Purpose/Description

This test provides an assessment of lower-extremity muscle strength.[3] It may also be used to examine functional status, balance, and vestibular dysfunction.

Equipment

Stopwatch and armless chair (43 cm high, 47.5 cm deep). Use consistent chair when monitoring change over time so that the chair seat height remains constant. Testing takes less than 1 minute. A practice trial may be given.

Administration

- Subjects sit in the armless chair with their trunk against the back.
- Subjects cross their arms over their chest.

- Subjects are allowed to place their feet comfortably under them during testing.
- Timing begins when examiner says "go" and stops when the subject's buttocks touch the chair on the fifth repetition.

Instructions From Examiner

- *I want you to stand up and sit down five times as quickly as you can when I say "go."*
- *Stand up fully between repetitions and to not touch the back of the chair during each repetition of sitting down.*

Test Results: Time _____ seconds (to 0.1 second)

Developers: Csuka M, McCarty DJ. Simple method for measurement of lower extremity muscle strength. *Am J Med*. 1985;78:77–81.

SECTION 2: BALANCE INTERVENTION

Intervention

Balance issues that result from c/mTBI are often related to vestibular deficits. Balance retraining programs improved symptoms in military personnel with dizziness associated with TBI.[124,125] Task and environmental conditions may influence balance when impairments are present. Therapists should consider modifying the complexity of balance tasks (simplify to allow success) and analyze the effects of reducing environmental complexity on balance as a part of the examination and intervention process. Typically, a program begins with simple balance tasks done in a quiet environment and slowly progresses the task demands and task environment so as to avoiding overwhelming a service member with a balance disorder, especially if it occurs in connection with vestibular deficits. Balance retraining programs include progressively more challenging tasks and environments,[126] including sports and martial arts activities to make them relevant for service members. Additionally, posturography platforms may be considered in treatment situations to provide practice adjusting to altered platform stability and sensory conditions.[124] The expectation for carryover from posturography platform training to improvement in functional abilities should be examined in c/mTBI. While the use of posturography in persons with stroke has resulted in improved static standing balance, improvement did not carry over to functional activities in the stroke population.[127]

For a progressive balance intervention program related to residual vestibular deficits, see Chapter 2: Vestibular Assessment and Intervention. For those complex patients who have been assessed using the BESTest, the identified subsystems can be used as the basis for designing an individualized treatment program. For example, deficits in biomechanical constraints may indicate a need for specific strengthening or stretching, or for further assessment in footwear.

Background

Given that balance deficits that arise in conjunction with c/mTBI typically occur as a result of vestibular dysfunction, a vestibular rehabilitation program (see Chapter 2: Vestibular Assessment and Intervention) often resolves the balance deficits. Significant

improvements in balance after vestibular rehabilitation are reported and are believed to be "related to habituation or adaptation of the central nervous system, sensory substitution, or reweighting of the sensory systems."[128] Information on recovery of balance issues following c/mTBI is primarily available as it relates to return to sports.[129] High-level balance dysfunction may be more evident after the service member has been stressed by exercise or intense work. Therapists should be aware of the need to increase task challenges progressively and monitor perception of exertion accordingly. Note that factors such as specific diagnosis, emotional state, age, and symptom duration may all affect the outcome of intervention for balance deficits.[128]

Strength of Recommendation: Practice Option

Descriptive studies have shown that balance retraining programs improve symptoms in military personnel with dizziness associated with TBI.[124] Evidence for precise balance retraining interventions has not been found specific to individuals with c/mTBI. Suggestions presented here are taken from the literature regarding vestibular rehabilitation, motor learning, stroke, and the elderly.[128] Balance retraining as part of a vestibular rehabilitation program is considered a **practice standard**. The use of CDP platforms has been suggested for balance retraining, though evidence for carryover for improvements in abilities on CDP have not yet been shown in persons with c/mTBI as it relates to clinical measures of balance.

Intervention Methods

- Provide education and training on a graded exercise program with a slow, symptom-free return to full activity. Encourage the symptom-free implementation of a progressive fitness program as tolerated, incorporating activities and sports that challenge balance while recognizing the need for safety and the avoidance of a second injury (see Chapter 2: Vestibular Assessment and Intervention).
- Educate the service member regarding adaptability of the nervous system and the need to challenge the nervous system to facilitate recovery. The service member should understand that avoiding activity because of symptom provocation may delay recovery.
- A "Points to Remember" sheet is included for therapists designing balance and strengthening intervention programs.
- When appropriate, the specific subsystems identified on the BESTest[4] or Mini-BESTest[11] as contributing to balance or strength deficits can be used as the basis for designing an individualized treatment program.

**HIGHER-LEVEL BALANCE AND FUNCTIONAL ABILITIES:
THERAPIST POINTS TO REMEMBER**

- The ability to avoid reinjury (impaired visual-spatial skills and postural control) is often diminished for weeks to a few months following c/mTBI, even when clinic-based assessments are normal. Design of an individualized balance retraining program **must** take into account safety and avoidance of a second injury.
- Dual tasks that combine cognitive and physical abilities may more closely simulate the complexities of service member duties. For a service member, individual task components may test as normal, but a problem emerges when multiple tasks are combined.
- Studies on specific balance retraining programs following c/mTBI are limited because function typically returns to baseline within a few weeks to 3 months following c/mTBI. Many of the suggestions for balance interventions come from studies on moderate to severe TBI, stroke, and other patient populations.[130,131] Chapter 10: Fitness Assessment and Intervention, in this toolkit, and new Return to Activity Clinical guidelines published by the Defense and Veterans Brain Injury Center (2013) should be reviewed prior to initiating intensive balance retraining programs where heart rate and blood pressure significantly increase.[132]
- Given that balance deficits following c/mTBI (specifically blast-related c/mTBI) are often related to vestibular deficits, initial balance retraining activities should be graded and interventions designed to avoid sensory overload. Tasks that require

head turning or gaze stability while moving may be especially challenging if there are vestibular deficits. The service member who becomes overly symptomatic during balance exercises will likely not comply with a retraining program.

- As with all learning tasks, important variables to consider when retraining postural control are the quantity, duration, and intensity of training sessions.[133] Evidence on the optimum frequency and duration of practice for balance activities specifically following c/mTBI is not yet available.
- Learning and retraining are enhanced by training specificity, motivating activities important to the individual (leisure or work related), and varied feedback schedules. Eventual progression of activities that include military occupation-related tasks, such as climbing into and over vehicles and walls, completing obstacle courses, negotiating uneven terrain, crawling, altering speeds, and adapting to environmental complexity are encouraged, as long as safety and avoidance of a second injury are considered.
- When designing and analyzing tasks for progression of balance programs, the therapist may want to consider Gentile's taxonomy[134] and evaluate the environment (stationary or in motion), the body (body is stable or in transport), and whether or not there is manipulation (hand use). Advancing all three contexts or components of tasks simultaneously may overwhelm some service members.
- Virtual-reality–based games and activities may provide the intensity and motivation important to retraining balance in this population.[133]
- Preliminary evidence indicates that exercise programs such as Tai Chi Chuan (commonly known as tai chi) provide at least short-term benefits in health status, mood, and self-esteem in persons with TBI,[131] as well as improved balance and reduced risk of falls in older persons.[135,136]
- Consider a water-based, balance retraining program as an adjunct to land-based therapies; there may be reduced fear of falling and injury while in an aquatic environment during challenging balance tasks[137] (ensure the environment does not exacerbate vestibular complaints).

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FITNESS AND CONDITIONING PROGRAM FOR BALANCE RETRAINING FOLLOWING VESTIBULAR DYSFUNCTION

A fitness and conditioning program should be introduced as soon as tolerated. This program should include balance retraining or a walking or stationary cycling program to combat fatigue secondary to deconditioning. All healthy adults aged 18 to 65 years need moderate-intensity aerobic physical activity for a minimum of 30 minutes on 5 days each week, and activities to increase muscular strength and endurance for a minimum of 2 days each week.[138] Exercise may improve mood and aspects of health status in individuals with TBI.[139]

The following specific suggestions may be made to the service member:

- Start slowly and increase the duration and intensity of your exercises over time.
- Monitor your heart rate or rate of perceived exertion.
- Vary your exercise program to keep from becoming bored.
- Use a calendar, notebook, or smartphone to keep track of your exercise days and times.

Activity suggestions include:

- Walking or stationary cycling to combat fatigue secondary to deconditioning. When cleared by the referring physician, progress

to other aerobic exercises, such as running and swimming.[140]

- Avocational activities that are fun and that challenge balance and vision simultaneously, such as:
  ○ golf,
  ○ bowling,
  ○ tennis,
  ○ racquetball,
  ○ ping-pong,
  ○ dancing,
  ○ cycling,
  ○ cross-country skiing, or
  ○ hiking.
- Alternative balance activities, such as tai chi or other noncontact martial arts or yoga.
- Incorporate service-specific physical fitness requirements for running, pushups, and sit-ups (see Chapter 10, Fitness Assessment and Intervention, for service-specific websites).

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