From the 2006 NIDRR SCI Measures Meeting Outcome Measures for Gait and Ambulation in the Spinal Cord Injury Population

Gait and Ambulation Subcommittee:

Amie B. Jackson, MD¹; Charles T. Cernel, MD¹; John F. Ditunno, MD²; Mary Schmidt Read, PT, DPT, MS³; Michael L. Boninger, MD⁴; Mark R. Schmeler, PhD, OTR/L APT⁵; Steve R. Williams, MD⁶; William H. Donovan, MD⁷

Received July 14, 2008; accepted August 24, 2008

Abstract

Background: At the 2006 National Institute on Disability and Rehabilitation Research (NIDRR) sponsored pre-conference on spinal cord injury (SCI) outcomes, several gait and ambulation measures were evaluated for utility in clinical practice, validity, and reliability as research measurement tools. The Conference Subcommittee on Gait and Ambulation chose to review the Walking Index for Spinal Cord Injury II (WISCI II), 50-Foot Walk Test (50FTWT), 6-Minute Walk Test (6MWT), 10-Meter Walk Test (10MWT), and Functional Independence Measure-Locomotor (FIM-L).

Methods: A subcommittee of international experts evaluated each instrument for test construct, administration, population applicability, reliability, sensitivity to change, and validity. Evaluations for each outcome measure were compiled, distributed to the whole committee, and then further reviewed with addition of comments and recommendations for consensus. An audience of experts voted on the validity and usefulness of each measure.

Results: WISCI II and 10MWT were found to be the most valid and clinically useful tests to measure improvement in gait for patients with SCI. FIM-L had little utility and validity for research in SCI. 6MWT and 50FTWT were found to be useful but in need of further validation or changes for the SCI population.

Conclusion: A combination of the 10MWT and WISCI II would provide the most valid measure of improvement in gait and ambulation in as much as objective changes of speed, and functional capacity allow for interval measurement. To provide the most comprehensive battery, however, it will be important to include a measure of endurance such as the 6MWT. Further validation and study should be devoted to WISCI II, 10MWT, and 6MWT as primary outcome measures for gait in SCI.

J Spinal Cord Med. 2008;31:487–499

Key Words: Spinal cord injuries; Evidence-based medicine; Outcomes research; Rehabilitation, physical; Ambulation; Gait, measurement

INTRODUCTION

In the field of spinal cord injury (SCI) research, there is an emphasis on ability to ambulate as a functional outcome and as an indicator of quality of life. Research investigating gait or locomotion, however, is difficult in that this complex set of movements requires a numerical value or scale so that measurements can be obtained at different time intervals to indicate improvement or decline. For the individual with SCI, ambulation depends on a variety of factors including level of injury, sensory preservation, proprioception, strength, locomotion mechanics, and spasticity. Presently, the Walking Index for Spinal Cord Injury II (WISCI II), 50-foot Walk Test (50FTWT), 6-Minute Walk Test (6MWT), Functional Independence Measure-Locomotor (FIM-L), and 10-Meter Walk Test (10MWT) are most commonly used in evaluating gait after SCI. To assess the strength of these outcome measures, one must address a variety of factors.

There are several issues in the construction and administration of an outcome measure that must be evaluated. The constant being measured must be identified and then a scale is created to gauge this property. Many of these locomotion scales measure velocity, distance, or work. Other tests use similar measures but also account for bracing by applying numerical values when it is used. Each patient's ability to understand the test, depending on its complexity, may also affect the results. Similarly, patient effort or discomfort can alter performance for the investigation. Also, test selection is often dependent on the researcher and will be affected by factors such as cost, specialized equipment, or time requirements.

Several gait measurement scales have been designed with the effects of cardiopulmonary disease, such as congestive heart failure or chronic obstructive pulmonary disease, in mind. Others have target populations such as

stroke, progressive neurological disease, or musculoskeletal disorders. In order to use these measurement scales in the SCI population, however, other considerations must be addressed. With cardiopulmonary disease, most limitations are metabolic or structural in nature, while with SCI, patients also have neuromuscular and mechanical impairments. Because of these additional issues, the original construction and administration of these tests may restrict their use. In some instances, adjustments have been made to accommodate these factors, which include age, bracing, level, and completeness of injury. As a result, normative values will vary from the outcome measures' intended population.

This paper reviews the outcome measures presented at the pre-conference that are most applicable and valid to the SCI population. Each measure was evaluated with the standardized parameters as outlined by the conference organizers. Through this evaluation, the 2006 National Institute on Disability and Rehabilitation Research (NIDRR) sponsored pre-conference produced a consensus of valid outcome measures for gait in patients with SCI. We reviewed the strengths and weaknesses of WISCI II, 50FTWT, 6MWT, FIM-L, 10MWT and the conclusions of the preconference.

METHODS

A subcommittee of international experts was formed to select and evaluate current outcome measures used as indicators of improvement in gait and ambulation in the spinal cord injured population. A phone conference was held to determine the 5 to 10 most important outcome measures. Members of this committee chose the WISCI II, 50FTWT, 6MWT, 10MWT, and the FIM-L as the most

relevant tests to evaluate in this process. Standardized parameters for review were used and are outlined by Johnston and Graves (1). As some of these guidelines are intended for psychometric outcomes, the review process was modified as patient-oriented effects are of primary importance. Two subcommittee members were assigned to each outcome measure to review all current literature pertaining to that test.

Johnston's manuscript provides the rating form utilized in the review process, which outlines a systematic approach to evaluating physical and biological constructs. A thorough literature review was performed using MEDLINE, Ovid, and PubMed for every outcome measure. Each instrument was evaluated for test construct, administration, population applicability, reliability, sensitivity to change, and validity. Evaluations for each outcome measure were compiled, distributed to the whole committee, and then further reviewed via conference calls with addition of comments and recommendations for consensus. Finally, presentations on summarized findings for each outcome measure were given at the NIDRR-sponsored preconference. The audience of experts then voted on each measure's validity and need for improvement.

Walking Index for Spinal Cord Injury II

Of the outcome measures addressed in this article, WISCI II was specifically developed for the incomplete spinal cord injury (ISCI) population for use in clinical trials. This distinction is important as the 6MWT, 10MWT or 50FTWT were designed for target populations outside of SCI. WISCI II is not an adaptation of an existing measurement tool, but rather is designed to gauge ambulation with bracing, ambulation aids, variations in bracing, and physical assistance. Locomotor performance is gauged on a 0 to 20 hierarchical scale where a lower number indicates higher impairment. Test subjects must ambulate 10 meters on a level surface with reciprocal gait for 19 of the 21 levels and are ranked on this ordinal scale. Rank is dependent on the requirement of devices, braces, and physical assistance used to complete the 10-meter distance. To be scored at a certain level, subjects must use devices and physical assistance as strictly defined by the construct. If the subject fails to complete the distance, he or she is retested at a lower level in the scale until they are successful. This construct is effective for the SCI population because it is widely inclusive.

There are, however, limitations in administration and construction of the WISCI II. Subjects are expected to ambulate or complete the specified distance with reciprocal gait, yet many patients with ISCI use swing-though gait and do not fit the scheme of this test. The investigator must also take into account safety and he/she might artificially limit or aid the performance of the test subject. In this regard, participants may be encouraged or discouraged from attempting more independent levels of ambulation. Scoring also does not account for

This article is one in a series of NIDRR evidence-Based reviews. The SCI Measures Meeting was supported by grant funds from the National Institute on Disability and Rehabilitation Research, Office of Special Education and Rehabilitation Services in the US Department of Education.

¹Department of Physical Medicine and Rehabilitation, University of Alabama, Birmingham, Alabama; ²Department of Rehabilitation Medicine, Jefferson Medical College, Thomas Jefferson University, Philadelphia, Pennsylvania; ³SCI Program, Magee Rehabilitation Hospital, Philadelphia, Pennsylvania; ⁴Department of Physical Medicine & Rehabilitation Sciences, University of Pittsburgh, Pennsylvania; ⁵Department of Physical Medicine and Rehabilitation, Boston University Medical School, Boston, Massachusetts; ⁶Department of Physical Medicine and Rehabilitation, Memorial Hermann Hospital & TIRR, and Baylor College of Medicine, Houston, Texas.

Please address correspondence to Charles T. Cernel, MD, Department of Physical Medicine and Rehabilitation, University of Alabama at Birmingham, 1717 6th Avenue South, Birmingham, Alabama 35213; phone: 931.261.7200; fax: 205.975.9754 (e-mail: ccernel@hotmail.com).

© 2008 by the American Paraplegia Society

JSCM

walking speed, gait quality, or any assistance used to come from sit to stand. Despite these concerns, its simple construct, minimal equipment use, minor time requirements, and ease of understanding make it a promising outcome measure.

As part of the development of the test, inter-rater reliability was studied with 40 video recordings of test subjects. Ditunno et al found 100% agreement among investigators at 8 SCI centers who were asked to assign WISCI scores to the recordings (2). Intra-rater reliability was demonstrated with calculated correlation coefficients in another study by van Hedel HJ. ($r > .97$) (3). There is some limitation, however, in the ability of the test to measure improvement in gait between 3 and 6 months following ISCI compared to 6MWT and 10MWT (4). WISCI II shows good sensitivity to change in patients with more impaired gait, while the 6MWT and 10MWT are superior in subjects with better ambulatory function (4). One might expect this difference as the WISCI II does not incorporate elements of speed or endurance, which has been a criticism by the authors (2,5) and others (4). Also, the use of this test in patients with SCI who have severe impairments in locomotion (WISCI II scores <10) did not correlate well with other timed walking tests (3). As a result, the ranking of levels and the use of the test in patients with poor ambulation has been questioned (3). WISCI does not account for gait quality and was found to be less sensitive to changes in gait in chronic subjects during clinical trials on automated locomotor training than the 10MWT, 6MWT, and Timed Up and Go (TUG) test (6). Overall, WISCI II has better sensitivity than timed walking tests in gauging locomotor improvement in a subset of patients with ISCI who are more impaired. The test also provides baseline data at WISCI 1 and 2 before 10 meters can be achieved, however, it has the limitation of a ceiling effect.

The hierarchical scale of the test was examined for face validity in a 2-center pilot study and then among 8 SCI centers (2). Participants assigned a numerical rank (0–20) to the test's scale components (physical assistance, braces, walker, crutches, and cane) in order to determine which combinations represented more or less impaired ambulation. There was statistical significance in the blinded rank orderings of test items by participants in both studies. Kendall coefficient of concordance was $W = 0.843$ $P < 0.001$ for the pilot study and $W = 0.860$ $P < 0.001$ in the 8 SCI center study (2).

Concurrent validity of WISCI II was examined in comparison to the Functional Independence Measure (FIM) (Spearman's rank correlation coefficient = $.765$, $P < 0.001$) (2). WISCI II also correlated well with walking tests like 10MWT, 6MWT, and TUG (3). It showed positive correlation with other criterion oriented scales such as the Barthel Index (BI) ($r = 0.67$, $P < 0.001$), Rivermead Mobility Index (RMI) ($r = 0.67$, $P < 0.001$), Spinal Cord Independence Measure (SCIM) ($r = 0.97$, $P < 0.001$), and

FIM ($r = 0.7$, $P < 0.001$) (5). It was also more sensitive to improvements in gait compared to these scales.

The WISCI II scale is widely inclusive and applicable to SCI research, but is relatively new. The test has demonstrated content reliability, inter and intra-rater reliability, criterion validity, and concurrent validity. The test may be insensitive, however, to change in recovery of walking function for patients with poor locomotor ability. With further use, it will likely demonstrate good clinical utility. Incorporation of speed and endurance in the test would likely help to increase its sensitivity to change, particularly in test subjects with highly functional ambulation.

10-Meter Walk Test

Although no specific patient population has been identified as the target population for the 10MWT, it has been used for gait assessment in stroke, Parkinson disease, and other neurological movement disorders. More recently the test has been successfully utilized in the SCI population. The test is a measure of functional capacity rather than physical disability, and following an ISCI, alterations in gait mechanics, strength, and proprioception will have a direct effect on the speed of walking. For this test, participants must ambulate 10 meters while being timed so that their walking speed may be calculated. A "flying start" is used where the subject may accelerate 2 meters before entering the timed 10-meter distance and 2 meters to decelerate afterwards. Speed is only calculated for the 10-meter distance between the "end zones." As long as subjects are able to ambulate the required 14 meters, they are able to participate in the test. Though no numerical adjustment is made in scoring, the patients may walk with physical assistance, braces, or any ambulation aids needed to complete the 10-meter distance. Because no adjustment is made for these aids, the test is often used alongside other outcome measures of gait such as WISCI II. No distinction needs to be made between subjects using reciprocal or swing-through gait.

The investigator, as in other tests, is responsible for the safety of the participants and may artificially limit walking speed. Speed may also be affected by the test subjects' effort. Subjects are instructed to walk at their preferred speed and this differs from the 50-foot walk in which subjects were instructed to walk at their maximal speed. Similar to other timed walking tests, the 10MWT has only been used more recently with patients with SCI and no normative values for walking speed in the SCI population exist. There are, however, age and gender specific normative values for the general population that can be used in comparison. Overall, this is a simple test that requires only one investigator. It is both time and cost effective and requires no special equipment to administer.

Intra and inter-rater reliability of the 10MWT was demonstrated by Van Hedel et al in the SCI population

Walking Index for Spinal Cord Injury (WISCI II) Descriptors

Physical Limitation for walking secondary to impairment is defined at the person level and indicates the ability of a person to walk after spinal cord injury. The development of this assessment index required a rank ordering along a dimension of impairment, from the level of most severe impairment (0) to least severe impairment (20) based on the use of devices, braces and physical assistance of one or more persons. The order of the levels suggests each successive level is a less impaired level than the former. The ranking of severity is based on the severity of the impairment and not on functional independence in the environment. The following definitions standardize the terms used in each item:

Physical assistance: 'Physical assistance of two persons' is moderate to maximum assistance.
'Physical assistance of one person' is minimal to moderate assistance.

Braces: 'Braces' means one or two braces, either short or long leg.
(Splinting of lower extremities for standing is considered long leg bracing).
'No braces' means no braces on either leg.

Walker: 'Walker' is a conventional rigid walker without wheels.

Crutches: 'Crutches' can be Lofstrand (Canadian) or axillary.

Cane: 'Cane' is a conventional straight cane.

Level	Description
0	Client is unable to stand and/or participate in assisted walking.
1	Ambulates in parallel bars, with braces and physical assistance of two persons, less than 10 meters.
2	Ambulates in parallel bars, with braces and physical assistance of two persons, 10 meters.
3	Ambulates in parallel bars, with braces and physical assistance of one person, 10 meters.
4	Ambulates in parallel bars, no braces and physical assistance of one person, 10 meters.
5	Ambulates in parallel bars, with no braces and no physical assistance, 10 meters.
6	Ambulates with walker, with braces and physical assistance of one person, 10 meters.
7	Ambulates with two crutches, with braces and physical assistance of one person, 10 meters.
8	Ambulates with walker, no braces and physical assistance of one person, 10 meters.
9	Ambulates with walker, with braces and no physical assistance, 10 meters.
10	Ambulates with one cane/crutch, with braces and physical assistance of one person, 10 meters.
11	Ambulates with two crutches, no braces and physical assistance of one person, 10 meters.
12	Ambulates with two crutches, with braces and no physical assistance, 10 meters.
13	Ambulates with walker, no braces and no physical assistance, 10 meters.
14	Ambulates with one cane/crutch, no braces and physical assistance of one person, 10 meters.
15	Ambulates with one cane/crutch, with braces and no physical assistance, 10 meters.
16	Ambulates with two crutches, no braces and no physical assistance, 10 meters.
17	Ambulates with on devices, no braces and physical assistance of one person, 10 meters.
18	Ambulates with on devices, with braces and no physical assistance, 10 meters.
19	Ambulates with one cane/crutch, no braces and no physical assistance, 10 meters.
20	Ambulates with no devices, no braces and no physical assistance, 10 meters.

Copy Freely – Do Not Alter

Copyright 2004-5. Thomas Jefferson University. All rights reserved

Figure 1. Walking Index for Spinal Cord Injury II.

Scoring Sheet for the Walking Index for Spinal Cord Injury (WISCI II)

Name _____

Date _____

Check descriptors that apply to current walking performance, and then assign the highest level of walking performance. (In scoring a level, one should choose the level at which the patient is safe as judged by the therapist, with patient's comfort level described. If devices other than those stated in the standard definitions are used, they should be documented as descriptors. If there is a discrepancy between two observers, the higher level should be chosen.)

Gait: reciprocal _____; swing through _____

Descriptors

Devices	Braces	Assistance	Patient reported Comfort level
//bars < 10 meters	Long Leg Braces- Uses 2 Uses 1	Max Assist x 2 people	Very comfortable
//bars 10 meters	Short Leg Braces- Uses 2 Uses 1	Min/Mod assist x 2 people	Slightly comfortable
Walker- Standard Rolling Platform	Locked at knee _____ Unlocked at knee _____	Min/mod assist x 1 person	Neither comfortable nor uncomfortable
Crutches- Uses 2 Uses 1	Other: _____		Slightly uncomfortable
Canes- Quad Uses 2 Uses 1			Very uncomfortable
No devices	No braces	No assistance	

WISCI Levels

Level	Devices	Braces	Assistance	Distance
0				Unable
1	Parallel bars	Braces	2 persons	Less than 10 meters
2	Parallel bars	Braces	2 persons	10 meters
3	Parallel bars	Braces	1 person	10 meters
4	Parallel bars	No braces	1 person	10 meters
5	Parallel bars	Braces	No assistance	10 meters
6	Walker	Braces	1 person	10 meters
7	Two crutches	Braces	1 person	10 meters
8	Walker	No braces	1 person	10 meters
9	Walker	Braces	No assistance	10 meters
10	One cane/crutch	Braces	1 person	10 meters
11	Two crutches	No braces	1 person	10 meters
12	Two crutches	Braces	No assistance	10 meters
13	Walker	No braces	No assistance	10 meters
14	One cane/crutch	No braces	1 person	10 meters
15	One cane/crutch	Braces	No assistance	10 meters
16	Two crutches	No braces	No assistance	10 meters
17	No devices	No braces	1 person	10 meters
18	No devices	Braces	No assistance	10 meters
19	One cane/crutch	No braces	No assistance	10 meters
20	No devices	No braces	No assistance	10 meters

Level assigned _____

Revised 3/19/2002

Copy Freely – Do Not Alter

Copyright 2004-5. Thomas Jefferson University. All rights reserved

Figure 1. Continued.

The following elements should be present on the 6MWT worksheet and report:

Lap counter: _____

Patient name: _____ Patient ID# _____

Walk # _____ Tech ID: _____ Date: _____

Gender: M F Age: _____ Race: _____ Height: _____ ft _____ in, _____ meters

Weight: _____ lbs, _____ kg Blood pressure: _____ / _____

Medications taken before the test (dose and time): _____

Supplemental oxygen during the test: No Yes, flow _____ L/min, type _____

	Baseline	End of Test
Time	____:____	____:____
Heart Rate	_____	_____
Dyspnea	_____	_____ (Borg scale)
Fatigue	_____	_____ (Borg scale)
SpO ₂	_____ %	_____ %

Stopped or paused before 6 minutes? No Yes, reason: _____

Other symptoms at end of exercise: angina dizziness hip, leg, or calf pain

Number of laps: _____ (×60 meters) + final partial lap: _____ meters =

Total distance walked in 6 minutes: _____ meters

Predicted distance: _____ meters Percent predicted: _____ %

Tech comments:

Interpretation (including comparison with a preintervention 6MWD):

Figure 2. 6-Minute Walk Test.

(3). Correlation coefficients for inter rater reliability were $r = .974$, $P < 0.001$ and $r = .983$, $P < 0.001$ for intra rater reliability (3). It has also demonstrated reliability in other populations such as stroke (test retest/ICC .87–.88) (7), Parkinson disease (test retest/ICC .87) (8), and other neurological conditions (inter-rater reliability $r = .93$, intra rater $r = .990$, test-retest $r = .89$ –.90) (9,10). Inter rater reliability in patients with SCI is better than intra rater reliability (3). Test repeatability was dependent on the effort and performance of the patient (3). The 10MWT correlated well with WISCI II in patients with American Spinal Injury Association (ASIA) D after initial injury and at 3 months (4). It also showed more sensitivity in patients with greater than 90% recovery of Lower Extremity Motor Score (LEMS) at 6 and 12-months post injury (ASIA

D) (4). Bias, however, may confound the reliability of this test. Here, age-referenced values may need to be used to interpret data as age negatively affects walking speed (3). Also, on sequential evaluations, the subject may “learn” the test which may alter their performance (11). Lastly, in patients with poor walking ability, sequential testing demonstrated poor reliability as there was increased variability in recorded values (3).

The sensitivity of the 10MWT to detect changes in locomotion is better than the WISCI II particularly in subjects who have less impairment due to the ceiling effect of that test (4). The 10MWT does, however, have a ceiling and floor effect as some subjects are unable to ambulate 10 meters and others are able to walk much farther than 10 meters with the same walking speed. The

floor effect may limit entry of severely injured individuals until they can walk the 14 meters required to perform the test. Its sensitivity to change in ambulation is more comparable to other gait speed tests such as the 6MWT because similar traits are being measured (4). Responsiveness to change has also been shown in the stroke population using a modified 6-meter distance as a variation of the 10MWT (12). Sensitivity of the 10MWT is also better than the LEMS for a longer period (6 months) (4). The outcome measure is less sensitive to change in locomotion in chronic SCI where there is little change in strength (6).

Construct validity has been demonstrated for the 10MWT by comparison with LEMS. Here, when looking at the level of neurological recovery and walking capacity, 10MWT and 6MWT were superior to LEMS in patients with ISCI with good walking abilities (4). Concurrent validity was established along with 6MWT and TUG as they correlated well with WISCI II. Correlation coefficients were $>.97$ when the tests were compared (3). Information, however, from the Van Hedel study may not be generalizable to the broader SCI population because test subjects were not randomly recruited.

The 10MWT shows good clinical utility as it correlated well with WISCI II and will be useful in clinical practice and research to assess locomotion in the incomplete spinal cord injured population (3,9). Speed (10MWT) and endurance (6MWT) tests can also be used as an indicator for transitions in some treatment modalities (10). The measure does not account for ambulation aids or assistance, but when combined with the WISCI II, it should provide a more accurate assessment of improvement in walking ability (4). Overall, this outcome measure has shown good validity, reliability, and clinical utility. It is a time and cost-effective test that is easy to understand and simple to administer as it requires little specialized equipment. The test has already proven itself in several populations with neurological impairments and will likely perform well in the SCI population. When combined with an additional test, such as WISCI II, it will be better able to show improvements in walking ability in the SCI population.

6-Meter Walk Test

The 6MWT is another walk-distance test that has been used in the SCI population. It was initially intended as an assessment tool in patients with respiratory impairment and was an adaptation of an existing 12-minute walking test (13–16). It has been studied in populations such as Parkinson disease, stroke, the elderly, healthy adults, and children. Modifications of this test have been adapted for those individuals who are unable to walk for the entire 6-minute time period. A patient's cardiovascular, pulmonary, and neuromuscular function will affect the test results. Participants ambulate on a hard flat surface for 6 minutes where the total distance walked is recorded (17). Occasionally, speed or velocity is calculated and used as a

secondary measure (4). Other parameters that are recorded include pulse, oxygen saturation, and fatigue. Typically a standardized course is constructed indoors in a hallway of approximately 100 feet. Shorter lengths may decrease the distance walked in 6 minutes due to an increased number of turns for the subject. Also, circular or oval tracks and treadmills should not be used (17,18). American Thoracic Society (ATS) guidelines recommend that the subject “walk quickly,” use no warm up, receive instructions prior to start, and have standardized encouragement at given intervals (17). The guidelines also describe performing the test twice with an hour between the 2 tests. Here, the best score of the 2 tests should be recorded (17). Parameters for discontinuation of the test include chest pain, staggering, intolerable dyspnea, diaphoresis, and ashen appearance (17). Other absolute contraindications in the cardiopulmonary population are outlined in the ATS guidelines (17). Presently, normative values for this test exist for healthy adults and children as well as for subjects with pulmonary disease (11,19,20).

The 6MWT has proven itself reliable in populations other than SCI, including stroke ($ICC = .78$) (21), Parkinson disease ($ICC = .95$) (8), community-dwelling elderly ($ICC = .95$) (11), healthy children ($ICC = .94$) (19), and cardiovascular disease ($ICC = .88-.91$) (22). The test has also demonstrated good reliability in the SCI population. For acute and subacute SCI, high correlation coefficients were found for inter ($r > .97$) and intra-rater reliability ($r > .98$) (3). The test correlated well with other self-paced gait speed tests in time intervals up to 12 months (3,4,23,24). The 6MWT correlated well with 10MWT and WISCI II 2 months post injury, but that relationship decreased over time (4). It also correlated well with 10MWT and TUG ($r > .88$), independent of a patient's walking ability (3,6).

Despite its proven reliability, several elements of bias can produce systematically high or low values with the 6MWT. Standardized instructions and test environments should be used to decrease a tester bias effect. The test environment is particularly important as a shorter course requiring more turns will decrease walking distances. Different levels of verbal encouragement may make significant differences in test performance (25). Repeated testing can produce a “training” or “practice” effect and improve a subject's performance (17). Patients with similar levels of injury may have widely varying scores due to the quality of their gait mechanics. Lastly, there should be some consistency in the use of bracing or assistive devices during the test as these differences will affect gait quality. Overall, reliability will be maintained provided the examiner follows established test guidelines and uses a standardized test environment.

The 6MWT has demonstrated good sensitivity to change in select populations. The test showed changes in walk distance after clinical interventions in respiratory patients (17). In patients with stroke, however, the test

LOCOMOTION: WALK: *Locomotion: Walk* includes walking on a level surface once in a standing position. The patient performs the activity safely. This is the first of two locomotion function modifiers.

NO HELPER

- 7 Complete Independence—The patient walks a minimum of 150 feet (50 meters) without assistive devices. The patient performs the activity safely.
- 6 Modified Independence—The patient walks a minimum of 150 feet (50 meters), but uses a brace (orthosis) or prosthesis on leg, special adaptive shoes, cane, crutches, or walkerette; or takes more than a reasonable amount of time to complete the activity; or there are safety considerations.
- 5 Exception (Household Locomotion)—The patient walks only short distances (a minimum of 50 feet or 15 meters) *independently* with or without a device. The activity takes more than a reasonable amount of time, or there are safety considerations.

HELPER

- 5 Supervision—The patient requires standby supervision, cueing, or coaxing to go a minimum of 150 feet (50 meters).
 - 4 Minimal Contact Assistance—The patient performs 75% or more of walking effort to go a minimum of 150 feet (50 meters).
 - 3 Moderate Assistance—The patient performs 50 to 74% of walking effort to go a minimum of 150 feet (50 meters).
 - 2 Maximal Assistance—The patient performs 25 to 49% of walking effort to go a minimum of 50 feet (15 meters), and requires the assistance of one person only.
- Total Assistance—The patient performs less than 25% of effort, or requires the assistance of two people, or walks to less than 50 feet (15 meters).
- 0 Activity Does Not Occur—Enter code 0 only for the admission assessment. The patient does not walk. For example, use 0 if the patient uses only a wheelchair for locomotion or the patient is on bed rest.

COMMENT: If the patient requires an assistive device for locomotion (prosthesis, walker, cane, AFO, adapted shoe, etc.), then the Locomotion: Walk score can never be higher than level 6.

There are two locomotion function modifiers. Score both function modifiers on admission and discharge. On the FIM™ instrument item 39L, the mode of locomotion (Walk or Wheelchair) must be the same on admission and discharge. If the patient changes the mode of locomotion between admission and discharge (usually wheelchair to walking), record the admission mode and scores based on the *more frequent mode of locomotion at discharge* on the FIM™ instrument.¹ Indicate the most frequent mode of locomotion (Walk or Wheelchair). If both are used about equally, code "Both."

Copyright ©2001 - 2004 UB Foundation Activities, Inc. (UBFA, Inc.) for compilation rights; no copyrights claimed in U.S. Government works included in Section I, portions of Section IV, Appendices I and K, and portions of Appendices B, C, E, G, H and J. All other copyrights are reserved to their respective owners. Copyright ©1993-2001 UB Foundation Activities, Inc. for the FIM Data Set, Measurement Scale, Impairment Codes, and refinements thereto for the IRF-PAI, and for the Guide for the Uniform Data Set for Medical Rehabilitation, as incorporated or referenced herein. The FIM mark is owned by UBFA, Inc.

Figure 3. Functional Independence Measure-Locomotion: Walk.

LOCOMOTION: WALK

Walk includes walking, once in a standing position, on a level surface. At level 7 the patient walks a minimum of 150 feet (50 meters), in a reasonable time, without assistive devices. Performs independently and safely. There are two function modifiers. Score both function modifiers on admission and discharge. On the FIM™ instrument, the mode of locomotion (Walk) must be the same on admission and discharge. If the patient changes the mode of locomotion between admission and discharge (usually wheelchair to walking), record the admission mode and scores based on the *more frequent mode of locomotion at discharge* on the FIM™ instrument. Indicate the most frequent mode of locomotion (Walk). If both are used about equally, code "Both."

Copyright ©2001 - 2004 UB Foundation Activities, Inc. (UBFA, Inc.) for compilation rights; no copyrights claimed in U.S. Government works included in Section I, portions of Section IV, Appendices I and K, and portions of Appendices B, C, E, G, H and J. All other copyrights are reserved to their respective owners. Copyright ©1993-2001 UB Foundation Activities, Inc. for the FIM Data Set, Measurement Scale, Impairment Codes, and refinements thereto for the IRF-PAI, and for the Guide for the Uniform Data Set for Medical Rehabilitation, as incorporated or referenced herein. The FIM mark is owned by UBFA, Inc.

Figure 3. Continued.

showed less sensitivity to change than the 12 MWT (21). For incomplete SCI, both the 6MWT and 10MWT demonstrated the ability to detect improvements of walking capacity in subjects with less impaired ambulation in acute injury and 6 months post injury, while the WISCI II and LEMS did not (4,6). Also, changes in 6-minute walk distance have been reported in acute SCI with associated increases in muscle strength, functional capacity measures, disability measures, and other timed tests (3,6,26). Sensitivity for the 6MWT is affected by a floor effect among patients who cannot walk for 6 minutes. Upright resting is allowed during the test, but if the subject sits, then he/she is disqualified. Similarly, a ceiling effect is seen in patients who can continue walking beyond 6 minutes at the same pace.

Concurrent validity has been demonstrated with the 6MWT when compared to the TUG, 10MWT, and WISCI II (3). It has also been used as a secondary outcome measure in a randomized multicenter trial on locomotor training in SCI and correlated with improvements in LEMS, balance, speed, WISCI II, and locomotor FIM in ASIA C/D subjects (26). Unfortunately, the test's predictive validity has not been established in the SCI population. This contrasts the respiratory impaired population where the test has proven to be a predictor of functional status, morbidity, and mortality (17,18). Furthermore, in patients with cardiopulmonary disease, the 6MWT is presently used as a measurement of clinical improvement pre and post intervention and for justification to continue certain medical interventions.

Despite the 6MWT's established reliability, validity, and clinical utility in cardiopulmonary patients, few formal studies have been performed in SCI. The outcome measure shows promise as being a good global assessment of endurance. Care, however, needs to be taken so that the administration of the test is standardized among participants. Further correlation with significant outcomes in SCI should also be sought to establish the test's clinical utility.

50-Foot Walk Test

The 50FTWT is another outcome measure that assesses walking speed. Initially it was designed to measure walking function in patients with musculoskeletal disorders including osteoarthritis (27,28), rheumatoid arthritis (29,30), low back pain (31,32), and geriatric (aging) conditions (33,34). In these circumstances, factors such as joint swelling, stiffness, and inflammation effect walking speed. It has established its usefulness as a stand alone outcome measure or as a battery of measures in these disorders. It has not been well studied in SCI, but was used as the primary endpoint and was found to have good reliability for a multi-center trial. It correlated well with improvements in strength (26) and other tests of functional capacity and disability after ISCI, including WISCI, FIM-L, and LEMS (26). In the stroke population, the 50FTWT has

been introduced as a primary outcome measure in a trial assessing the ability of a drug to improve strength (35).

Participants in the test are instructed to walk a marked 50-foot distance where they are timed so that their velocity may be calculated. Subjects are given an acceleration and deceleration zone of two steps before entering the timed distance and can walk at a self selected, comfortable, or maximal speed. In the clinical trial on locomotor training in SCI the subjects were instructed to walk at maximal speed. Like other timed distance tests, patients must be able to complete the 50-foot distance in order to participate in the test. Normative data exist in the literature for osteoarthritis and rheumatoid arthritis (27–30).

While this walking speed test is gaining more attention, there are no reported norms for SCI. Inter and intra-rater reliability for the 50FTWT has been demonstrated in persons with musculoskeletal disease (31, 32, 34). Increases in walking speed as measured by 50FTWT correlated with increases in scores in WISCI II and LEMS at 3 and 6 months post SCI (26). Three-month walking speeds when compared to 6-month speeds also showed a linear relationship (26). As with all walking tests, a floor-and-ceiling effect does affect the test's sensitivity to change. Here, subjects who cannot walk 50 feet are unable to participate in the measurement. Also, those who can walk the distance at a fast pace may also be able to walk a greater distance at that same speed.

Unlike other walking tests described above, the 50FTWT has not been formally compared to other walking measures to determine its criterion validity. It has shown good correlation over time with other outcome measures including motor strength, balance, 6MWT, WISCI II, and FIM-L demonstrating its concurrent validity in a weight-supported treadmill vs overground training for walking trial after acute ISCI (26). No formal study has been performed to evaluate the test's predictive validity in this population, but the LEMS was predictive of the other walking outcome measures in the same clinical trial (26). Though the 50FTWT has been primarily used for research purposes, it also satisfies the condition of "household distance" in the FIM scale where the ability to cover 50 feet in a reasonable time is of clinical significance.

Overall, this test has shown formal reliability and validity in patients with musculoskeletal disorders including osteoarthritis, rheumatoid arthritis, and low back pain. More formal testing, however, should be performed in order to prove its reliability and validity in the SCI population. Like other tests of walking speed, it is a simple test that is easily administered, requires no specialized equipment, and is of little cost.

Functional Independence Measure-Locomotor

FIM-L, a subscale of the FIM has been used in the stroke and SCI populations (26,36–38). FIM was designed for use with all disabilities. A score is assigned on a 7-point

	VALID OR USEFUL (VOTES)	USEFUL BUT REQUIRES VALIDATION OR CHANGES (VOTES)	NOT USEFUL OR VALID FOR RESEARCH IN SCI (VOTES)	TOTAL VOTES
10 Meter Walk Test	32 (60%)	20 (38%)	1 (2%)	53
WISCI II	28 (52%)	23 (43%)	3 (6%)	54
50 Foot Walk Test	13 (25%)	31 (60%)	8 (15%)	52
6 Minute Walk Test	19 (37%)	30 (58%)	3 (6%)	52
FIM L	3 (6%)	18 (36%)	29 (58%)	50

Figure 4. Audience Voting Results.

scale depending on the assistance used to ambulate: 1 is equal to total assistance, 2 maximum assistance with 1 person, 3 is moderate assistance, 4 minimal assistance with hands on contact, 5 supervision, 6 modified independence (with equipment), and 7 independent without equipment. Unlike many other ambulation tests, the FIM-L has two distinct subscales. This construct allows individuals with widely varying ability to participate as one subscale is for walking while the other is for wheelchair. Scoring is dependent on the aids or assistance used to cover a distance over level ground up to 150 feet. The construct of the test is simple, it is easy to administer and only requires that the participant bring the equipment needed to ambulate.

Concerning reliability, the FIM-L was designed as a tool to measure the burden of care and will be a more reliable measure in subjects with more impaired ambulation and lower LEMS such as ASIA B. Presently, no formal reliability studies exist for this test in the SCI population. In the case studies on locomotor training, the test failed to show a change in one subjects' score pre and post training despite their mode of ambulation changing from wheelchair to walking (38). Similarly, a participant may be able to walk 150 feet independently, but may have considerable difficulty walking further distances. A ceiling effect is revealed in that the test shows poor sensitivity to change in subjects with better walking abilities. Also, scoring of the FIM-L does not account for the speed with which test subjects complete the required distances.

FIM-L correlated well with WISCI ($r = .88-.92$), Berg Balance Scale (BBS) ($r = .90-.92$), and LEMS (.85-.89) in the multicenter trial at all time points (26). In the same study though, WISCI showed better sensitivity in that subjects placed in one FIM-L level had several different WISCI scores. In the case study manuscript, the test was also insensitive to detecting changes in subjects ambulating at greater distances, progressing in walking speed or demonstrating improvement in limb coordination (38).

FIM-L scores were used in a clinical trial and were found to be inaccurate in predicting outcomes (26). The clinical usefulness of the FIM-L is also limited, particularly in patients with ASIA C and D SCI, as it is less sensitive to detecting changes in those who are able to ambulate more independently. The test is a good measure of the assistance needed to ambulate but not of the overall ambulatory capacity of the participant.

Audience Consensus

During the preconference on SCI outcomes, the audience of 54 experts was asked to vote on the gait and ambulation measures presented. Each test was appraised in 3 categories: valid or useful, useful but requires validation or changes/improvements, not useful or valid for research in SCI.

Overall the audience voted the 10MWT and WISCI II as the most valid and useful outcome measures for assessment of recovery in gait and ambulation in the SCI population for clinical research (Figure 4). The 10MWT and WISCI II are measures of functional capacity that have proven validity and reliability in SCI population-specific studies. Both of these tests did, however, have 38% and 43%, respectively, of the audience endorsing further validation and improvement. (Figure 4). Of the other tests presented in this manuscript, only FIM-L had a greater than 50% score as being "not useful or valid for research in SCI" (Figure 4). The 50FTWT and the 6MWT had 60% and 58%, respectively, of the audience vote as being useful, but requiring further validation or improvement (Figure 4).

CONCLUSIONS AND RECOMMENDATIONS

In individuals with SCI, natural gait patterns and locomotion are significantly altered because of decreased strength, endurance, proprioception, use of bracing, and spasticity. Reliable, valid, sensitive and clinically useful measures of gait are needed to evaluate new interventions and therapies in the field of SCI. The subcommittee has found that 10MWT and WISCI II are the most valid

and clinically useful tests in evaluating improvements in gait and ambulation following SCI. Both of these measures, however, do not address endurance and the 6MWT should be included to provide the most comprehensive battery of tests. Though these tests have shown validity and clinical utility in the current literature, they would benefit from further validation and study. Additionally, continued use of these measures will help to establish normative values in the SCI population. We must also determine what influence a patient's satisfaction and perception of their ambulation should have on measurements of improvement in gait.

It has been suggested that the concurrent use of quantitative measurements of gait, such as the 10MWT, and a functional measure, such as WISCI II, would be superior to either test alone. The quantitative measure might improve clinical significance as it relates to the subjects' walking speed and might serve as a marker of the participant's ability to function in the community, such as crossing a busy street. A test of endurance should be added, such as the 6MWT, as it would reveal a subject's ability to walk farther distances and would help to address the ceiling effect in the scale of both the WISCI II and 10MWT. Last, the functional capacity measure would provide descriptive information on the level of locomotor recovery of the participant and what assistance and aids are used in ambulation. Overall, the combination of 10MWT, 6MWT, and WISCI II would provide a comprehensive tool to measure changes in gait and ambulation following interventions in the SCI population. Further validation and study should be devoted to WISCI II, 10MWT, and 6MWT as primary outcome measures for gait in SCI.

REFERENCES

- Johnston MV, Graves DE. Towards guidelines for evaluation of measures: an introduction with application to spinal cord injury. *J Spinal Cord Med*. 2008;31:13–26.
- Ditunno JF, Ditunno P, Graziani V, et al. Walking index for spinal cord injury (WISCI): an international multicenter validity and reliability study. *Spinal Cord*. 2000;38(4):234–243.
- van Hedel H, Wirz M, Dietz V. Assessing walking ability in subjects with spinal cord injury: validity and reliability of 3 walking tests. *Arch Phys Med Rehabil*. 2005;86(2):190–196.
- van Hedel H, Wirz M, Curt A. Improving walking assessment in subjects with an incomplete spinal cord injury: responsiveness. *Spinal Cord*. 2006;44(6):352–356.
- Morganti B, Scivoletto G, Ditunno P, Ditunno J, Molinari M. Walking index for spinal cord injury (WISCI): criterion validation. *Spinal Cord*. 2005;43(1):27–33.
- Wirz M, Zemon D, Rupp R, et al. Effectiveness of automated locomotor training in patients with chronic incomplete spinal cord injury: a multicenter trial. *Arch Phys Med Rehabil*. 2005;86(4):672–680.
- Collen F, Wade D, Bradshaw C. Mobility after stroke: reliability of measures of impairment and disability. *Int Disabil Stud*. 1990;12(1):6–9.
- Schenkman M, Cutson T, Kuchibhatla M, Chandler J, Pieper C. Reliability of impairment and physical performance measures for persons with Parkinson's disease. *Phys Ther*. 1997;77(1):19–27.
- Rossier P, Wade D. Validity and reliability comparison of 4 mobility measures in patients presenting with neurologic impairment. *Arch Phys Med Rehabil*. 2001;82(1):9–13.
- Hornby T, Zemon D, Campbell D. Robotic-assisted, body-weight-supported treadmill training in individuals following motor incomplete spinal cord injury. *Phys Ther*. 2005;85(1):52–66.
- Steffen T, Hacker T, Mollinger L. Age- and gender-related test performance in community-dwelling elderly people: Six-Minute Walk Test, Berg Balance Scale, Timed Up & Go Test, and gait speeds. *Phys Ther*. 2002;82(2):128–137.
- Goldie P, Matyas T, Evans O. Deficit and change in gait velocity during rehabilitation after stroke. *Arch Phys Med Rehabil*. 1996;77(10):1074–1082.
- Balke B. A simple field test for the assessment of physical fitness. REP 63–6. *Rep Civ Aeromed Res Inst US*. 1963;53:1–8.
- Cooper K. A means of assessing maximal oxygen intake. Correlation between field and treadmill testing. *JAMA*. 1968;203(3):201–204.
- McGavin C, Gupta S, McHardy G. Twelve-minute walking test for assessing disability in chronic bronchitis. *Br Med J*. 1976;1(6013):822–823.
- Butland R, Pang J, Gross E, Woodcock A, Geddes D. Two-, six-, and 12-minute walking tests in respiratory disease. *Br Med J (Clin Res Ed)*. 1982;284(6329):1607–1608.
- Brooks D, Solway S, Gibbons W. ATS statement on six-minute walk test. *Am J Respir Crit Care Med*. 2003;167(9):1287.
- Enright P. The six-minute walk test. *Respir Care*. 2003;48(8):783–785.
- Li A, Yin J, Yu C, et al. The six-minute walk test in healthy children: reliability and validity. *Eur Respir J*. 2005;25(6):1057–1060.
- Enright P, Sherrill D. Reference equations for the six-minute walk in healthy adults. *Am J Respir Crit Care Med*. 1998;158(5 Pt 1):1384–1387.
- Kosak M, Smith T. Comparison of the 2-, 6-, and 12-minute walk tests in patients with stroke. *J Rehabil Res Dev*. 2005;42(1):103–107.
- Demers C, McKelvie R, Negassa A, Yusuf S. Reliability, validity, and responsiveness of the six-minute walk test in patients with heart failure. *Am Heart J*. 2001;142(4):698–703.
- Kim C, Eng J, Whittaker M. Level walking and ambulatory capacity in persons with incomplete spinal cord injury: relationship with muscle strength. *Spinal Cord*. 2004;42(3):156–162.
- Eng J, Chu K, Dawson A, Kim C, Hepburn K. Functional walk tests in individuals with stroke: relation to perceived exertion and myocardial exertion. *Stroke*. 2002;33(3):756–761.
- Guyatt G, Pugsley S, Sullivan M, et al. Effect of encouragement on walking test performance. *Thorax*. 1984;39(11):818–822.
- Dobkin B, Apple D, Barbeau H, et al. Weight-supported treadmill vs over-ground training for walking after acute incomplete SCI. *Neurology*. 2006;66(4):484–493.
- Chang R, Falconer J, Stulberg S, Arnold W, Manheim L, Dyer A. A randomized, controlled trial of arthroscopic

- surgery versus closed-needle joint lavage for patients with osteoarthritis of the knee. *Arthritis Rheum.* 1993;36(3):289–296.
28. Williams H, Ward J, Egger M, et al. Comparison of naproxen and acetaminophen in a two-year study of treatment of osteoarthritis of the knee. *Arthritis Rheum.* 1993;36(9):1196–1206.
 29. Brown B, Daenzer C, Hearn M, Johnson J. Comparison of two dosing schedules of flurbiprofen for patients with rheumatoid arthritis. Twice-daily versus four-times-a-day schedules. *Am J Med.* 1986;80(3A):19–22.
 30. Førre O, Bjerkhoel F, Salvesen C, et al. An open, controlled, randomized comparison of cyclosporine and azathioprine in the treatment of rheumatoid arthritis: a preliminary report. *Arthritis Rheum.* 1987;30(1):88–92.
 31. Lee C, Simmonds M, Novy D, Jones S. Self-reports and clinician-measured physical function among patients with low back pain: a comparison. *Arch Phys Med Rehabil.* 2001;82(2):227–231.
 32. Simmonds M, Olson S, Jones S, et al. Psychometric characteristics and clinical usefulness of physical performance tests in patients with low back pain. *Spine.* 1998;23(22):2412–2421.
 33. Li F, Fisher K, Harmer P. Improving physical function and blood pressure in older adults through cobblestone mat walking: a randomized trial. *J Am Geriatr Soc.* 2005;53(8):1305–1312.
 34. Reuben D, Siu A. An objective measure of physical function of elderly outpatients. The Physical Performance Test. *J Am Geriatr Soc.* 1990;38(10):1105–1112.
 35. Cramer SC. Trial of ropinirole in motor recovery after stroke. NIH Clinical Trials Site. Irvine, CA: University of California; 2005.
 36. Yagura H, Hatakenaka M, Miyai I. Does therapeutic facilitation add to locomotor outcome of body weight-supported treadmill training in nonambulatory patients with stroke? A randomized controlled trial. *Arch Phys Med Rehabil.* 2006;87(4):529–535.
 37. Teixeira da Cunha Filho I, Lim P, Qureshy H, Henson H, Monga T, Protas E. A comparison of regular rehabilitation and regular rehabilitation with supported treadmill ambulation training for acute stroke patients. *J Rehabil Res Dev.* 2001;38(2):245–255.
 38. Behrman A, Harkema S. Locomotor training after human spinal cord injury: a series of case studies. *Phys Ther.* 2000;80(7):688–700.

ERRATA

Author name/e-mail address corrections

J Spinal Cord Med. 2008;31(3):309–311. Groothius JT [corrected to Groothuis JT] j.groothius@maartenskliniek.nl [corrected to j.groothuis@maartenskliniek.nl] Correct citation: Groothuis JT, van Kuppevelt DH. Postpartum spinal cord injury in a woman with HELLP Syndrome. *J Spinal Cord Med.* 2008;31(3):309–311 Department of Rehabilitation Medicine, St. Maartenskliniek, Nijmegen, The Netherlands. j.groothuis@maartenskliniek.nl
PMID: 18795483 [PubMed - in process]

Affiliation correction

J Spinal Cord Med. 2008;31(3):319–323.
Lee KW, Han SJ, Kim DJ, Lee M. Spinal epidural abscess associated with moxibustion-related infection of the finger.
Department of Rehabilitation Medicine, School of Medicine, Ewha Womans University [corrected to Ewha], Seoul, Republic of Korea.
PMID: 18795486 [PubMed - in process]