Disease Progression in Multiple Sclerosis
II. Methods for the Determination of Walking Impairment and Its Impact on Activities and Social Participation

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Abstract
Walking ability is a vital component of validated test procedures to assess mobility impairment in multiple sclerosis (MS). The methods used to assess walking ability vary widely between treatment centres, and the accuracy of the methods used and numbers of parameters determined to analyse specific aspects of walking and gait are often limited. The questionnaire- and task-based methods used to assess walking in MS can be divided into different categories. First, there are the general-purpose tests such as the Expanded Disability Status Scale (EDSS), the Multiple Sclerosis Functional Composite (MSFC), the Family Assessment of Multiple Sclerosis Trial Outcome Index (FAMS-TOI) and the Short Form-36 (SF-36). These, particularly EDSS, are widely used in MS to assess limitations of all activities and social participation, of which walking is only a part. Others, such as SF-36, assess health-related quality of life (HRQoL). Second, there are methods designed to specifically assess walking or gait, including the timed 25-foot walk (T25FW), the Dynamic Gait Index (DGI), the 12-Item MS Walking Scale (MSWS-12) and the Timed Up and Go Test (TUGT). These test methods require minimal equipment to perform such as a stopwatch, a hallway or a chair, and can be completed at a medical centre in a few minutes. Most of these tests provide reliable and valid data but some lack accurate assessment of gait and some require clinician training. Third, there are tests that specifically measure balance, such as the Berg Balance Test, in which the patient completes a series of balance exercises while being observed. A recent development is the use of accelerometers to monitor MS patients over extended periods; these can provide more accurate data than patient self-report tools. In future, it is likely that more specific tests of walking ability will be more widely used as an important part of MS diagnosis and to more precisely monitor disease progression and assess patient needs.

Keywords
Multiple sclerosis, walking impairment, ambulation tests, gait, balance, mobility determination methods

Disclosure: Jürg Kesselring serves or has served on data safety monitoring and advisory boards of clinical trials in multiple sclerosis sponsored by Biogen, Novartis, Serono, Schering and Wyeth.
Acknowledgement: Editorial assistance was provided by James Gilbart at Touch Briefings.
Received: 14 June 2010 **Accepted:** 1 July 2010 **Citation:** *European Neurological Review*, 2010;5(1):61–8 *DOI:10.17925/ENR.2010.05.01.61*
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Support: The publication of this article was funded by Biogen Idec, Inc. The views and opinions expressed are those of the author and not necessarily those of Biogen Idec, Inc.

Overview of Disability and Walking Impairment in Multiple Sclerosis
In multiple sclerosis (MS), walking ability is an important component of a variety of validated measures of mobility impairment.[1–3] The methods used to assess the degree of impairment vary widely between studies, investigation groups and treatment centres, and few of the more commonly used approaches determine walking impairment with sufficient precision. In fact, subtle changes in walking ability can indicate early stages of neurodegeneration, but these signs are not used as a central part of the diagnostic process in MS. Moreover, detailed changes over time are rarely monitored in sufficient detail at any disease stage. The continued accurate monitoring of mobility is important in determining both the treatments and support needs of patients. A variety of methods have been used to assess outcome measures in patients with MS in many studies.[4] The most frequently used scales determine disability and mobility only as a component of overall disease assessment, but many neurologists and rehabilitation specialists argue that these do not provide an adequate assessment of mobility and certainly fail to capture small changes that can indicate the gradual accumulation of neuronal loss.[5–7] The purpose of this article is to outline the more commonly used methods of general disability assessment in MS and also the methods for specifically analysing walking ability, gait, balance and the likelihood of falling. It will also discuss the advantages of some of these test methods and consider the clinical studies in which they have been used.

Methods for General Assessment of Activities and Social Participation in Multiple Sclerosis
In clinical studies of MS, and in regular practice, a variety of methods are used for the general assessment of activities and social participation. Many of these methods were designed for application in different diseases or across a general health spectrum; some were designed to assess overall health-related quality of life (HRQoL) and,

Table 1: General Tests Used for Assessment of Disability in Multiple Sclerosis

Test Method	Type/Purpose (Assessor)	Details of Assessments Included	Equipment Needed, Time to Perform and Cost	Validity of Data, Advantages/Disadvantages
Expanded Disability Status Scale (EDSS)	Questionnaire/general determination of disability status and disease progression (requires a trained examiner, usually a neurologist).	Rates patients on a scale of 0 (normal) to 10 (death due to MS) in 0.5 increments based on increasing disability. Largely based on mobility (see *Table 2*).	Test form, pen. 15–30 minutes to complete. Minimal cost.	Widely used test method, data valid but mobility assessments limited in scope. Has poor psychometric properties and a modest inter-rater reliability; lacks linearity.[10]
Multiple Sclerosis Functional Composite (MSFC)	Multidimensional tests/three practical methods measure walking ability, hand/eye motor function and cognitive function (trained examiner).	A timed T25FW to measure leg function/ambulation. 9HPT to measure arm/hand dexterity. PASAT to measure cognitive function.	Stopwatch, pen, test forms, peg test board, pegs. 20–30 minutes to complete. Low cost.	Excellent test–retest reliability. Concurrent validity was demonstrated by significant correlations with the EDSS, SF-36 and the Sickness Impact Profile.[16]
Family Assessment of MS Trial Outcome Index (FAMS-TOI)	Questionnaire-based/provides overall assessment of disability (trained examiner).	59 questions in 6 subscales: mobility, symptoms, emotional wellbeing (depression), general contentment, thinking/fatigue and family/social wellbeing.	Test form, pen. 20–30 minutes to complete. Minimal cost.	Good internal consistency of the derived subscales, test–retest reliability, content, concurrent and construct validity.[19,47]
MS Impairment Scale (MSIS)	Standard neurological examination/scale is a measure of accumulated deficits assessed (neurologist, requires neurological diagnostic expertise).	The MSIS score is the sum of 53 subscores (theoretical range of 0–204 points). Scores are drawn from assessments of accumulated neurological defects grouped into 7 types.	Extended questionnaire. >30 minutes to complete. Minimal cost.	Studies show responsiveness of the MSIS is better than the EDSS for magnitude and stability over the range of measurement.[48]
MS Self-Efficacy (MSSE)	Questionnaire/two subscales measure function and control (patient-completed questionnaire).	18 items on two subscales: the function scale measures confidence with functional abilities, and the control scale measures confidence with ability to manage symptoms and to cope with the demands of illness.	Test form, pen. Few minutes to complete. Minimal cost.	Shows good internal consistency and reliability in the overall scale and the function and control subscales.[49]
MS Impact Scale-29 (MSIS-29)	Questionnaire (29 questions) in two sections: physical and psychological impact (patient-completed questionnaire).	20 questions on mobility and motor skills (MSIS-29-PHYS) and 9 questions on illness, depression, state of mind, confidence (MSIS-29-PSYCH). Each question/item scores 0, 1, 2, 3 or 4.	Test form, pen. Few minutes to complete. Minimal cost.	The 2 subscales are unidimensional and show good internal consistency; not biased by the sex or age of patients.[22] MS-specific.
88-item MS Spasticity Scale (MSSS-88)	Questionnaire/addresses 8 areas (patient-completed questionnaire, which can be mailed to patients).	88 questions in 8 subscales: muscle stiffness, pain and discomfort, muscle spasms, activities of daily living, walking, body movement, emotional health, social functioning.	More time-consuming than other test methods due to number of questions. Minimal cost except for investigator time interpreting data.	Reliable and valid, patient-based, interval-level measure of the impact of spasticity in MS.[2] MS-specific.
MS Severity Scale (MSSS)	Questionnaire/variation of EDSS method to take account of disease duration (trained examiner).	Algorithm scores EDSS to the distribution of disability in patients with comparable disease durations and creates a global MSSS figure.	Requires computer software algorithm and EDSS forms. Minimal cost.	A powerful method for comparing disease progression using single assessment data. The test is useful for comparing groups of patients but it is not appropriate as a predictor of future disability in an individual due to fluctuation in parameters measured.[14] MS-specific.
Scripps Neurological Rating Scale	Questionnaire/summary measure of individual components of a neurological examination for use in MS (trained examiner).	22 parameters, mainly neurological signs with one addressing gait trunk and balance. Scores: -10 (severe) to 100 (normal).	Simple to perform. 10–20 minutes. Minimal cost.	Good coverage of neurological signs but assessment of walking and mobility limited to one parameter only.[50,51]
Health Utilities Index (HUI)	Questionnaire/a general-purpose health assessment of 8 subscales (mark 3 version), describes health status for population health studies (patient-completed questionnaire).	8 areas: vision, hearing, speech, ambulation, dexterity, emotion, cognition and pain. Each attribute consists of multiple levels.	Requires no equipment. 5 minutes. Minimal cost.	Provides detail on each attribute and captures combinations of deficits and summaries of HRQoL.[21]

Table 1 continued

Test Method	Type/Purpose (Assessor)	Details of Assessments Included	Equipment Needed, Time to Perform and Cost	Validity of Data, Advantages/Disadvantages
Short Form-36	Questionnaire/physical and mental components. Includes 36 questions to determine QoL; 9 questions concern mobility (supervised assessment by patient).	Components: vigorous activities (e.g. running), moderate activities (e.g. bowling or playing golf), lifting or carrying groceries, climbing flights of stairs, bending, kneeling or stooping, walking ≥1 mile, walking several blocks or one block.	Test form, pen. 30 minutes. Minimal cost.	Widely used test method to assess overall QoL. Has several mobility elements but is not sufficiently precise to adequately assess mobility.[52]
Barthel Index	Questionnaire/measures daily functioning focusing on the activities of daily living and mobility (trained examiner).	10 questions on feeding, bathing, grooming, dressing, bowels, bladder, toilet, transfer, mobility and stairs. Scored 0, 5, 10 or 15, or 0, 1, 2 or 3 (maximum = 100 or 20).	Test form, pen. Few minutes to complete. Minimal cost.	Good variability and small floor and ceiling effects. Shown to be as good as the functional independence measure for evaluating change.[53]

9HPT = 9-hole peg test; HRQoL = health-related quality of life; PASAT = Paced Auditory Serial Addition Test; PHYS = physical; PSYCH = psychological; T25FW = 25-foot walk.

therefore, determination of mobility is only a component or subscale within a larger set of assessments. Thus, the detail these methods provide in determining mobility is limited, as they address many aspects of the disease. An overview of the more frequently used general methods for such assessment in MS is given in *Table 1*.

The most frequently used scale in MS mobility assessment is the Expanded Disability Status Scale (EDSS),[8,9] which rates disability progression on a range of 0.0–10.0 in increments of 0.5. The rating is usually performed by a neurologist. The criteria used to define the EDSS score are given in *Table 2*. EDSS is considered a 'standard' method and is almost universally recognised by neurologists. It has therefore often been used as part of the inclusion criteria for numerous MS clinical trials and is also commonly used to rate patients in clinical practice.[7] Despite its wide utilisation, EDSS has also been much criticised because it defines ambulation only in terms of the distance a patient can walk and assistance needed; qualitative changes are not assessed and it is considered by some to be insufficient to fully assess disability.[7] Further criticisms include poor psychometric properties,[10] a modest inter-rater reliability and lack of linearity.

Increasing disability, as indicated by rising EDSS scores, is closely associated with the degree of neurological pathology (particularly the extent of lesions and decreased brain volume) as detected by magnetic resonance imaging (MRI).[11–13] In an analysis of multiple studies in MS, a cross-sectional correlation was reported between MRI T_2 parameters and EDSS scores in MS patients at different disease stages (correlation coefficients were 0.15 for secondary progressive MS (SPMS), 0.55 for CIS and 0.60 for relapsing–remitting MS [RRMS]). In a study of SPMS patients, a correlation of up to 0.81 between the presence of MRI black holes and EDSS scores was reported.[11] In other studies, the correlation between disability and MRI lesions in MS patients was considered to be weak, most likely owing to the unpredictable consequences of damage at different brain sites and the variable effects seen on neurological function.[12]

Another study in The Netherlands showed that during 12 years of follow-up of 46 patients with confirmed MS, increasing lesion loads, atrophy and axonal loss were associated with disease severity as determined by the MS Severity Score (MSSS).[13] The MSSS method is based on the EDSS, but uses an algorithm that incorporates the distribution of disability in patients with similar disease durations.

Table 2: The Expanded Disability Status Scale

EDSS Score	Disability Stage/Description
0.0	Normal neurological exam
1.0	No disability, minimal signs on 1 FS
1.5	No disability, minimal signs on 2 of 7 FS
2.0	Minimal disability in 1 of 7 FS
2.5	Minimal disability in 2 FS
3.0	Moderate disability in 1 FS, or mild disability in 3–4 FS, although fully ambulatory
3.5	Fully ambulatory but with moderate disability in 1 FS and mild disability in 1 or 2 FS, moderate disability in 2 FS or mild disability in 5 FS
4.0	Fully ambulatory without aid, up and about 12 hours a day despite relatively severe disability; able to walk 500 metres without aid
4.5	Fully ambulatory without aid, up and about much of day, able to work a full day, may otherwise have some limitations of full activity or require minimal assistance; relatively severe disability; able to walk without aid for 300 metres
5.0	Ambulatory without aid for about 200 metres; disability impairs full daily activities
5.5	Ambulatory for 100 metres; disability precludes full daily activities
6.0	Intermittent or unilateral constant assistance (cane, crutch or brace) required to walk 100 metres with or without resting
6.5	Constant bilateral support (cane, crutch or braces) required to walk 20 metres without resting
7.0	Unable to walk beyond 5 metres even with aid, essentially restricted to wheelchair, wheels self, transfers alone; active in wheelchair about 12 hours a day
7.5	Unable to take more than a few steps, restricted to wheelchair, may need aid to transfer; wheels self, but may require motorised chair for full day's activities
8.0	Essentially restricted to bed, chair, or wheelchair, but may be out of bed much of day; retains self-care functions, generally effective use of arms
8.5	Essentially restricted to bed much of day, some effective use of arms, retains some self-care functions
9.0	Helpless bed patient, can communicate and eat
9.5	Unable to communicate effectively or eat/swallow
10.0	Death due to MS

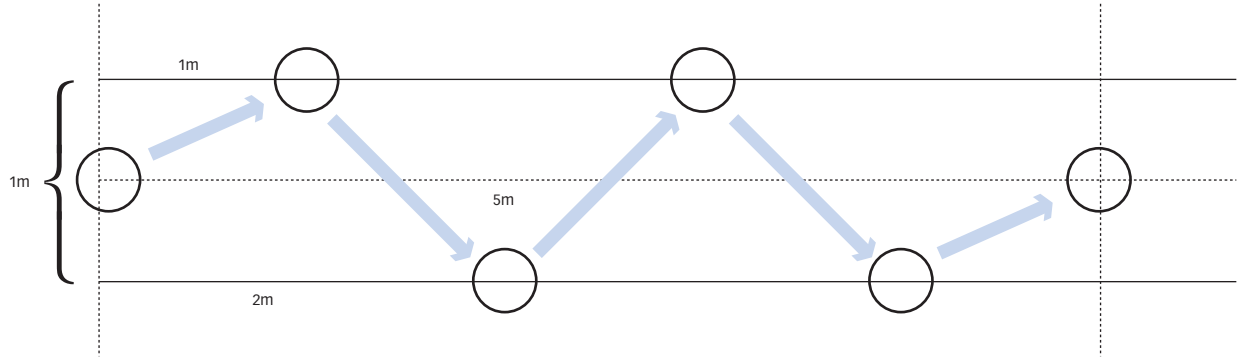
Levels of disability at each 0.5 increment in score. EDSS = Expanded Disability Status Scale; FS = functional systems (there are eight in EDSS); MS = multiple sclerosis.
Source: Kurtzke, 1983.[8]

Consequently, MSSS provides information about disease progression as well as current disability status[14] (see *Table 1*).

Table 3: Tests Used for the Specific Assessment of Walking and Gait in Multiple Sclerosis

Test Method	Purpose	Details of Assessments Included	Equipment Needed, Time to Perform and Cost	Validity of Data, Advantages/Disadvantages
Dynamic Gait Index	Assess aspects of gait and balance during walking.	Series of 8 tasks including walking at different speeds for fixed times, walking and keeping balance while head is turned or tilted, stepping over or around obstacles and climbing stairs.	Open area needed to conduct test. 20–30 minutes. Minimal cost.	Reliable functional assessment tool – inversely correlated with timed walk.[28]
12-Item Multiple Sclerosis Walking Scale (MSWS-12)	Provide a patient-based measure of walking ability in MS.	2 questions with responses rated on scale of 1 (not at all) to 5 (extremely). Questions ask if MS has decreased ability to walk, run, stand, walking difficulty and support needed. Interview with neurologist.	Tests forms, pen. 15–20 minutes. Minimal cost.	More responsive than Family Assessment of MS Trial Outcome Index (FAMS-TOI) mobility scale, the SF-36 Health Survey physical functioning scale and Expanded Disability Status Scale (EDSS).[1]
Timed 25 Foot Walking Test (T25FW)	Part of the MS functional composite (MSFC – see *Table 1*).	Patient is timed walking 25ft as fast as he/she is able without injury.	Open area, stopwatch, pen. Easy to conduct. Low cost.	High inter-rater and test–retest reliability and good concurrent validity.[37,38] Low responsiveness and floor and ceiling effects. Does not distinguish gait changes resulting from fatigue.
6 Minute Walking Test (6MWT)	Provide a measure of overall mobility and physical functioning.	Distance walked is measured over 6-minute time period; walking is self-paced.	Open area, stopwatch, pen. 6 minutes to complete plus time for recovery. Minimal cost.	Easy to administer. Provides valuable information on effects of fatigue on ambulation. Does not address qualitative changes or changes over the 6-minute period.[54]
Timed Up and Go Test (TUGT)	Assess propensity for falling and general mobility in the elderly.	Subjects are instructed to stand up, using chair armrests, walk to a line 3 metres away, turn and return to the chair.	Armchair, stopwatch, tape measure. 1–5 minutes to complete. Minimal cost.	As yet, there are no validity and reliability data for the MS population using the TUGT.[29–31]
Six Spot Step Test (SSST)	Quantitative measurement of ambulation in MS; a lower limb counterpart to 9-hole peg test.	Subject is required to walk down a marked test field/floor and push wooden blocks out of circles in a specific order with the same foot each time (see *Figure 1*).	Marked test field, wooden blocks, stopwatch. 5–10 minutes to complete. Low cost.	Only moderately correlated with EDSS and MS Impact Scale (MSIS). SSST superior to T25FW for dynamic range, floor effect and discriminatory power.[39]
Hauser Ambulation Index (HAI)	Subjective assessment of walking ability and dependence on a wheelchair.	Questions rate subjects on a scale of 1 (fully active) to 9 (wheelchair-bound and unable to transfer self independently). Walking time is used together with other factors to rate the patient on an ordinal scale with 11 gradations.	Stopwatch, test form, pen. 1–5 minutes to complete. Minimal cost.	Good test–retest and inter-rater reliability and convergent validity. Due to more desirable psychometric properties, the T25FW has largely replaced the HAI in clinical studies.[55]
Kinetic and Kinematic Analysis (KKA)	Provide precise, objective data on gait during walking.	Test determines force and angle of joints during gait cycle and provides data on spatial and temporal gait parameters.	Tests require special training and test equipment. High cost of equipment needed.	In KKA, biomechanics may not reflect activity limitations/participation restrictions. Moderate reliability in paediatric population but no data on application to MS population.[56]
Functional Independence Measure (FIM)	Assess physical and cognitive disability focusing on the burden of care. The test can be performed by any trained person.	Includes 18 items; 13 are physical domains based on the Barthel Index and 5 are cognition items. Each item is scored from 1 to 7 (1 = total dependence and 7 = complete independence). Scores range from 18 to 126 (higher = greater ability).	15 minutes to complete test. Requires training. Low cost.	Adequate to high inter-rater reliability and high internal validity. High concurrent validity with the Barthel Index, TUGT and the Tinetti Balance Test.[57,58]
Rivermead Mobility Index (RMI)	Assess aspects of mobility.	Patient is asked 15 questions regarding turning over in bed, lying to sitting, sitting balance, standing, stairs, getting up off the floor, bathing and running. All questions require a yes/no response; maximum score = 15.	Tests forms, pen. 5–10 minutes to complete. Minimal cost.	Studies indicate that the reliability and validity of RMI data are good.[59,60]
Observation	Clinical observation of patient's gait and walking ability in a controlled setting.	Patient is asked to walk while being observed by a neurologist.	Requires training to recognise normal and abnormal gait characteristics. 5–10 minutes to complete. Easy. Minimal cost.	This method has poor inter-rater reliability.[4]

Figure 1: Diagram of the Test Field for the Six Spot Step Test



The subject tested starts by standing on the circle at the left end of the field. The five wooden blocks are placed in the centre of the remaining circles. The subject walks criss-cross from one circle to the next while shoving the blocks out of the circles and the test field. The same leg is used for all blocks in one passage. The test is performed twice with each leg as the active limb.[39]

Another assessment of outcome is the MS Functional Composite (MSFC).[15,16] This test involves three quantitative components: a timed 25-foot walk (T25FW) to measure leg function and ambulation, a nine-hole peg test (9HPT) to measure arm and hand function and the Paced Auditory Serial Addition Test (PASAT) to measure cognitive function. These three components are used to produce a combined Z-score that indicates the overall relative difference from the mean of a non-diseased population. The reliability of the MSFC was demonstrated in a small study of 10 MS patients at a treatment centre in the US.[17] Repeated tests conducted by two technicians showed that the MSFC provided excellent reproducibility in terms of intra- and inter-rater variability. In another study, the T25FW and 9HPT were repeated for five consecutive days in 63 patients with MS from four different university treatment centres in the US. The results showed a <20% variation in individual mean scores.[18] It was concluded that changes >20% in MSFC scores were needed to reliably indicate a true change in function for a patient. This represents a substantial change in status and a weakness of this scoring system, which might not detect smaller or more subtle deteriorations in a patient's condition and may thus fail to alert the clinician to the need for improved treatments or support.

There are many other tests for assessing general MS status. Some of these are designed to assess HRQoL, e.g. the Family Assessment of MS Trial Outcome Index (FAMS-TOI), comprising the dimensions mobility, symptoms, emotional wellbeing, general contentment, thinking and fatigue, family and social wellbeing and additional concerns.[19] Specifically designed for assessing patients diagnosed with MS, this scale provides a comprehensive determination of disease status; the mobility subscale is highly predictive of EDSS and has been used in large-scale MS trials.[20] Other tests used in MS populations were designed to be used in various diseases affecting neurological abilities: the Health Utilities Index Mark 3 (HUI3), which assesses eight aspects of disease effects;[21] the MS Impact Scale-29 (MSIS-29), which addresses physical and psychological impact in two separate subscales;[22] and the Short Form-36 (SF-36).[23,24] The latter was primarily designed to assess various aspects of QoL in many different diseases and populations, with 25% (nine out of 36) of the questions relating to mobility (see *Table 1*). While these instruments provide good overall assessments of disease, the determination of mobility in each is inherently limited and the tests are considered by many to be insufficiently precise, or inappropriate, for accurately monitoring progression of mobility in MS patients. The perceived shortcomings in general disability test methods to specifically assess mobility in MS patients led some neurologists to call for improved methods and assessment scales to more precisely determine the parameters associated with walking ability, and for mobility to be more generally recognised as a major indicator of MS progression.[7,25]

Methods for Assessing Mobility and Gait in Multiple Sclerosis

Mobility tests are mostly simple, requiring minimal equipment or facilities, and can be completed within a few minutes. An overview of the more frequently used tests is given in *Table 3*. Some of these tests include an assessment of gait, a vital and complex factor influencing walking ability. Gait is affected by strength, motor control, range of motion and sensation. In MS, there is no one gait type that is characteristic of the disease, although some frequent gait features have been observed.[26,27]

A consensus meeting sponsored by the Consortium of MS Centers (CMSC) in 2009 developed recommendations for the determination of gait in MS.[4] It was agreed that this complex function can only be assessed by measuring a range of parameters. The participants recommended a set of five mobility tests considered to form a useful preliminary measure of gait in MS: T25FW, Dynamic Gait Index (DGI), 12-Item MS Walking Scale (MSWS-12), Timed Up and Go Test (TUGT) and the Six-Minute Walk (6MW). All of these assessments are easy to perform, require minimal equipment and provide reliable and valid data; some lack accurate assessment of gait and some require clinician training.

The MSWS-12 is a prominent example of a walking-ability test specifically developed for MS patients.[1] The test consists of 12 questions related to walking and running ability and the requirement for support. Responses are graded from 1 (ability not limited at all) to 5 (extremely limited ability). The test method was evaluated in a group of 78 patients with primary progressive MS (PPMS) and a separate group of 54 patients with PPMS (n=1), SPMS (n=16) or RRMS (n=37) who were receiving steroid treatment for relapses. The MSWS-12 findings in all patients were highly reproducible, and relative efficiency determinations showed the MSWS-12 to be more responsive (relative efficiency [RE] 1.0) than the FAMS-TOI mobility scale (RE 0.76), the SF-36 (RE 0.48), the EDSS (RE 0.31) and the T25FW (RE 0.64).

The DGI is a frequently used test, originally developed to assess the risk of falling, which comprises eight sets of tasks to assess various

Table 4: Tests Used for the Specific Assessment of Balance and Prediction of Falling in Multiple Sclerosis

Test Method	Purpose	Details of Assessments Included	Equipment Needed, Time to Perform and Cost	Validity of Data, Advantages/Disadvantages
Berg Balance Test	Measures ability to balance.	Subjects are challenged to maintain balance with narrowing base of support, starting seated and progressing to one leg standing. Measures weight shifting, turning and reaching. The highest score is 56 points. A score of 45 usually separates fallers from non-fallers.	Minimal equipment needed. Minimal cost.	Good reliability has been established in studies on the elderly but not in MS.[40]
Modified Clinical Test for Sensory Interaction on Balance	Examines postural sway in 4 conditions.	Patient's balance is examined with their eyes open or closed while being rocked on a moving platform, which has either a firm or a foam surface. Composite sway is the mean sway speed averaged over the 4 conditions.	High cost of equipment needed.	Test–retest reliability was high for standing on a firm surface with eyes open or closed.[42] Patient-perceived imbalance correlated poorly with assessment of postural stability.[43]
100% Limits of Stability Test	Maximum angle a person of a given height can sway the body over the feet without losing balance and taking a step.	Ability of patients to shift their centre of pressure from a centre point to 8 targets placed around the centre of pressure: front, sides, back and 4 diagonal points.	Requires a Balance Master instrument and experienced operator. 20–30 minutes to complete. High cost.	Moderate test–retest reliability of movement time to targets and path length to targets.[42]
Tinetti Performance Overall Mobility Assessment (POMA)	Two separate sections measuring balance and gait.	Balance: patient is asked to complete 9 tests including sitting, rising, standing and turning; maximum score 16. Gait: elements of a patient's gait are observed over 7 tests: step length, symmetry, continuity, path, walking stance; maximum score 12.	Chair, stopwatch, 15-inch walkway. 15 minutes to complete. Low cost.	Inter- and intra-rater reliability good to excellent when evaluated in Parkinson's disease patients; limited data available for use in MS.[41]

facets of gait. Performance is graded on a scale of 0–3. The neurologist or technician observes the patient performing tasks that include walking at different speeds for fixed time periods, walking while their head is turned and ability to avoid obstacles while walking. The DGI has been shown to be a reliable and valid method, the results of which are inversely correlated with results from a timed walk over a 6.1m distance.[28]

The TUGT was primarily designed as a means of assessing the risk of falling in the elderly, but it also addresses wider aspects of mobility.[29–34] This timed test requires subjects to rise from an armchair, walk three metres, return and sit down as quickly as they are able. Subjects with higher scores were generally less mobile and at greater risk of falling. A study of 413 community-dwelling and 78 institutionalised elderly women showed that reduced levels of physical activity and residence in an institution were strongly associated with poorer performance on the TUGT ($p<0.0001$ for both criteria).[31] The TUGT method is a useful assessment of mobility but evaluation in MS patients has been limited.[35,36] The T25FT is often used as a stand-alone test of mobility (see *Table 3*). As a measure of mobility it is limited in scope, as it only gauges walking speed and not other specific characteristics of gait or balance. The T25FT is an integral part of the MSFC test, which was discussed above under methods for general assessment of disability in MS.[37,38]

In addition to the five preliminary tests listed by the consensus group, the Six Spot Step Test (SSST) has recently been used to assess MS patients.[39] Patients are instructed to walk as quickly as possible between marked circles in a rectangular floor area measuring 1x5m following diagonal paths and knocking wooden blocks out of each circle using the same foot (see *Figure 1*). A study in Denmark and The Netherlands of 151 patients with MS showed that the SSST performed better than the T25FW in terms of dynamic range, floor effect and discriminatory power. It was suggested by the authors that this might be a better test to use as part of the MSFC described above, but further research is required.

There are many more tests of mobility that have been used for limited numbers of investigations in MS patients (see *Table 3*). The choice of test usually depends on investigator preference or established practice at each treatment centre. A simple alternative to these tests is observation in a controlled clinical setting; however, this approach requires experience and a thorough understanding of normal and abnormal gait and has poor inter-rater reliability.[4] Given the multiplicity of test methods available, it may be necessary to establish new guidelines that recommend particular methods and attempt to standardise assessments used at different treatment centres and in clinical trials.

Methods for the Assessment of Balance and Prediction of Falling in Multiple Sclerosis

Several different tests have been used in MS patients to specifically assess balance or assess it as part of a wider determination of mobility (see *Table 4*). Some of these tests, such as the Berg Balance Test, require no special equipment. The patient completes a questionnaire and is then asked to make a number of defined movements while initially sitting and then moving to a standing position and then finally balancing on one leg.[40] Results using this method showed that use of an

assistive device was a strong predictor of performance and that a score of 45 (out of 56) was a fairly reliable cut-off value that discriminated those susceptible to falling from those who were not. Another such test instrument is the Tinetti Performance Overall Mobility Assessment (POMA), which has two subscales addressing balance and gait. In the balance section, the patient completes nine timed tests that involve movements associated with sitting, rising, standing and turning. Only limited data are available for the use of this test in MS. Using POMA to retrospectively analyse records from 126 patients with Parkinson's disease showed good to excellent intra- and inter-rater reliability with an intra-class correlation coefficient of >0.80; the sensitivity and specificity of the test to identify fallers were 76 and 66%, respectively.[41]

Some other balance tests involve computer-controlled instrumentation, e.g. the Modified Clinical Test for Sensory Interaction on Balance.[42] The patient stands on a platform that has either a firm or a foam surface, and the platform is rocked following a pre-set programme. The patient's ability to balance is then tested with the eyes either open or closed to determine postural sway in different conditions. Using this equipment, the test–retest reliability was shown to be high, but the perception of imbalance of the patients did not correlate well with assessments of postural stability.[43] Methods requiring specialist equipment are confined to neurology centres and would not be available for assessing most MS patients.

Use of Devices to Monitor Mobility and Activity

When studying mobility in MS patients, it is necessary to monitor movement and exertion over extended periods. To achieve this, some investigators have conducted trials using accelerometers worn by MS patients to continuously monitor activity. These devices provide a good measure of both physical activity and walking compared with patient self-report methods, which tend to be more restricted in the range of parameters reported and for various reasons are likely to be less accurate.[44,45] In a study including 269 patients with RRMS, self-report questionnaires were effective at assessing either walking (using MSWS-12 and Patient-Determined Disease Steps) or physical activity (using the Godin Leisure-Time Exercise Questionnaire [GLTEQ] and International Physical Activity Questionnaire). However, no questionnaire was effective at assessing both aspects.[45] The use of accelerometers in the same set of patients provided an accurate assessment of both walking and physical activity.

A new tool for assessing gait in MS patients is the GaitRite® system, which consists of a portable walkway mat with an active area measuring 366x61cm containing a total of 13,820 pressure sensors.[46] When a patient walks over the walkway, the system is able to capture the geometry of each footfall and computes multiple temporal and spatial parameters. This enables a rapid and detailed analysis of gait, monitors change in parameters and compares them with normal performance. The system can also assess muscle weakness and determine risk of falling. This type of system for monitoring walking is new and is currently restricted to a limited number of treatment centres, but it has the potential to monitor patient walking performance more accurately than most of the currently used tests.

Future Developments in Mobility Assessment and Management in Multiple Sclerosis

Existing measures of disability are mostly elements of other tests that assess wider aspects of MS status and are too 'general-purpose' for an accurate assessment of walking ability and specific aspects of gait. The limitations of the more frequently used test methods may become more widely recognised, causing many neurologists to make greater use of more specific tests and questionnaires and to develop new instruments including wider-ranging questionnaires that will more accurately determine mobility and gait.

As mobility tests are inexpensive and require fewer resources than MRI or laboratory investigations, these new tests are likely to be increasingly used in clinical trials and routine monitoring of MS patients in clinical practice at MS centres and general clinics. These tests will be valuable when used in initial diagnosis, but their importance in monitoring pathological progression and for assessing the requirement for support and assistance of patients should not be underestimated.

Currently, the methods used both for general assessment of limitations of activities and social participation and for the more specific determination of walking ability, gait and balance are diverse and vary widely between treatment centres. As our understanding of the applicability of these tests to disease progression increases, we should begin to develop guidelines for the better assessment of mobility and gait in MS over time. This would also help to standardise methods used in clinical trials, making results more readily comparable, and would help, ensure that patient management and treatment are based on current best practice. ■

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