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The Six Spot Step Test: a new measurement for walking ability in multiple sclerosis

MM Nieuwenhuis^{1,2}, H Van Tongeren³, PS Sørensen¹ and M Ravnborg^{1,3}

Objective The primary objective of this study was to develop a quantitative test to assess ambulation in multiple sclerosis (MS) patients that is more accurate and sensitive than the Timed 25-foot walk (T25FW). For this purpose, we developed the Six Spot Step Test (SSST), which besides speed includes co-ordination and balance, to be a lower limb counterpart to the 9-Hole Peg Test (9HPT).

Background The T25FW, which is the ambulation test of the MS Functional Composite (MSFC), reflects only the speed component of walking. The lack of sensitivity to other components of gait adds to the floor effect.

Methods and patients In the SSST, the patient is instructed to walk as quickly as possible from one end to the other of a rectangular field measuring 1 × 5 m, while kicking five cylinder blocks out of five circles marked on the floor. Some 151 MS patients with the Expanded Disability Status Scale (EDSS) score 0–6.5 and 64 normal controls performed the SSST and the T25FW. In addition, 41 patients performed the tests twice.

Results The range of the SSST (4.7–35.1 seconds) was wider than that of the T25FW (3.5–22.6 seconds). Using control mean + 2 SD as cut off, 107 patients had abnormal SSST, while 100 patients had abnormal T25FW. The T25FW (mean) increased 2.1 seconds over the EDSS range of 0–4.0, while the SSST increased 4.9 seconds. The intra-class correlation between repeated tests (*r*) was 0.95 for the SSST and 0.96 for the T25FW. The correlation between the SSST and the T25FW was high (*r* = 0.92).

Conclusion The SSST seems to be superior to the T25FW in terms of dynamic range, floor effect and discriminatory power. The SSST is a relevant alternative for the T25FW as the ambulation component of the MSFC. *Multiple Sclerosis* 2006; 12: 495–500. www.multiplesclerosisjournal.com

Key words: ambulation; clinical assessment; EDSS; MSFC; MSIS; multiple sclerosis; outcome measure; SSST

Introduction

The Expanded Disability Status Scale (EDSS) [1] has been widely used as the primary outcome measure in multiple sclerosis (MS) clinical trials. Although it has been criticized for its poor psychometric properties, it still makes up the gold standard for clinical assessment of MS patients [2–5]. In response to growing dissatisfaction with the available clinical outcome scales, the Multiple Sclerosis Functional Composite (MSFC) was developed by the National

MS Society's Clinical Assessment Task Force [6–9]. The MSFC is a multidimensional outcome measure for clinical trials in MS research based on three ratio-interval scales of neurological functions: ambulation/leg function, arm/hand function and cognition. In comparison with the EDSS, the MSFC has been shown to be more valid, reliable and sensitive to clinically relevant change in several studies [10–13]. In particular, the components that measure arm function (9-Hole Peg Test; 9HPT) and cognition (PASAT-3) contain additional informa-

¹ Department of Neurology, Copenhagen MS Research Centre, Copenhagen University Hospital Rigshospitalet, Copenhagen, Denmark

² University of Nijmegen, Netherlands

³ The MS Rehabilitation Centre in Haslev, Haslev, Denmark

Author for correspondence: Mads Ravnborg, Department of Neurology, N2082, Rigshospitalet, DK2100 Ø, Denmark. E-mail: mravn@rh.dk

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tion when compared with the EDSS [14–17]. The ambulation component, the Timed 25-foot walk (T25FW), correlates strongly with the EDSS. However, the T25FW is hampered by a low responsiveness and has marked floor and ceiling effects. An important reason for the two first qualities is that the T25FW almost only reflects speed. The ceiling effect is inherent in the EDSS because values >6.5 in are not compatible with walking 25 feet.

We decided to develop an ambulation test that assesses lower limb function with a test paradigm parallel to the 9HPT. The performance in this test, called the Six Spot Step Test (SSST), reflects a complex array of sensori-motor functions, part of which are lower limb strength, spasticity and co-ordination, as well as balance. Similar to the T25FW, the SSST rely to some extent on vision and cognition.

Methods

A total of 151 patients with clinically definite MS and an EDSS between 0 and 6.5 were recruited and tested consecutively in the order they visited the Copenhagen MS Research Centre at the Copenhagen University Hospital (81 patients) and the MS Rehabilitation Centre in Haslev (70 patients). Of the patients from the MS Rehabilitation Centre in Haslev, 41 were re-tested after 1–2 hours to determine the re-test reliabilities of the SSST and T25FW. Sixty-four normal individuals were tested as controls. Individuals who had EDSS >6.5 and patients who could not see the whole test field were excluded from the study. All individuals performed the T25FW and the SSST as described below.

The SSST is a quantitative assessment of lower extremity function, which is measured in the time domain. The test field measures 1×5 m (width \times length). At the middle of each end line a circle, with a diameter of 20 cm, is marked. At each side-line, two circles of the same size are marked with a

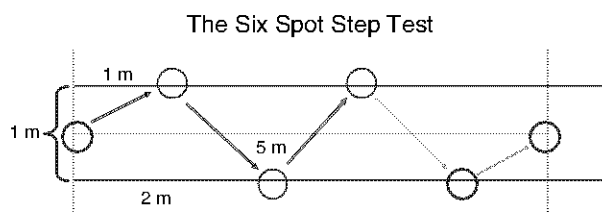


Figure 1 Diagram of the test field. The person tested starts standing on the circle at the left end of the field. The five wooden blocks are placed in the centre of the remaining circles. The test person walks criss-cross from one circle to the next while shoving the blocks out of the circles and the test field. One and the same leg is used for all blocks in one passage. The test is performed twice with each leg as the active limb.

distance from the end line of 1 and 3 m at one side and 2 and 4 m at the other side (Figure 1). Five wooden, cylinder blocks with a diameter of 8 cm and a height of 4 cm, weighing 134 g, are placed in the centre of the circles, except in one of the end-line circles, which is used as the starting point. The patient is instructed verbally and is shown by the examining technician how to perform the SSST. Starting with feet touching the circle at one end of the test field, the patient walks criss-cross from circle to circle and shoves the blocks out of the field with one foot, alternating between the lateral and the medial side of the foot. The patient is asked to do the test as fast as possible without running. The test result is the time used from lifting the foot from the start circle to shoving the last block out of the last circle. The patient has to do four runs, two for each leg. At each run, only one leg is used for shoving the blocks out of the field. During the test, assistive devices can be used if needed for safe performance of the test. In this validation the total-score of the SSST was the mean value of the four runs. The Appendix contains the extended administration and scoring manual of the SSST.

The T25FW was performed twice in accordance with the instructions of Rudick *et al.* [8,9], along a corridor separate from the SSST field. All MS patients also completed the 12-item MS Walking Scale (MSWS-12) [18]. It consists of a questionnaire with 12 items describing the impact of MS on ambulation. The questions ask about limitations to the patients walking ability due to MS during the past two weeks. The grading for each item ranges from 1 (not at all) to 5 (extremely). The subscores of the MSWS-12 were summed into a total score.

After giving informed consent, the patients completed the MSWS-12. Then, the examining technician showed the patient how to perform the SSST and the patients practised the SSST three times to compensate for possible practice effects. After a resting period of 5 minutes, the examining technician administered the T25FW and SSST. Half of the patients performed the T25FW first and the other half started with the SSST. The patients rested for 5 minutes between the two tests. The neurologist rated the patients on the EDSS and the MS Impairment Scale (MSIS) [19,20]. After resting 1–2 hours, 41 patients repeated the SSST and the T25FW to allow for calculation of the re-test reliabilities.

For all three measures, high scores indicated poor ambulation. The Spearman rank correlation test was used to calculate the co-variation of the scores of the different scales. Analysis of variance was performed to assess the effect of age, sex and the use of assistive devices on the study variables. Re-test reliabilities for the SSST and the T25FW were evaluated by means of intraclass coefficients (ICC). McNemar's test was used to test the difference in

the number of abnormal cases identified by the two ambulation tests.

Results

All 151 patients had a mean age of 42.2 years (SD 12.4), their EDSS scores ranged from 0 to 6.5 (mean 4.3, SD 2.0) and their MSIS scores ranged from 0 to 112 (mean 34, SD 25). EDSS and MSIS scores were not available for 11 and 18 patients, respectively. All demographic properties and mean scores of the patients group are summarized in Table 1. The 64 controls had a mean age of 38.6 years (SD 11.8).

The time to perform the SSST ranged from 4.7 to 38.7 seconds (median 10.7 seconds) in the MS patients (Figure 2b) compared with a median time of 6.4 seconds (SD 1.0) in the controls. The distribution in the MS patients was skewed towards the lower end of the time range. Only one patient was unable to perform the SSST with the non-dominant leg. For further analysis, the time for the run with the non-dominant leg was estimated by adding 20% to the time of the dominant leg.

The 151 patients performed the T25FW in 3.5–22.6 seconds (mean 7.1 seconds), with a skewed distribution towards the lower end of this range (Figure 2a). The median T25FW was 4.4 seconds (SD = 0.6) in controls.

Patients in the 20–39 years age group were significantly faster on the SSST and T25FW than patients from 40 to 80 years and scored significantly lower on the MSWS-12, EDSS and MSIS ($P < 0.05$). Patients using assistive devices were significantly slower on the T25FW and SSST than patients performing these tests without assistive

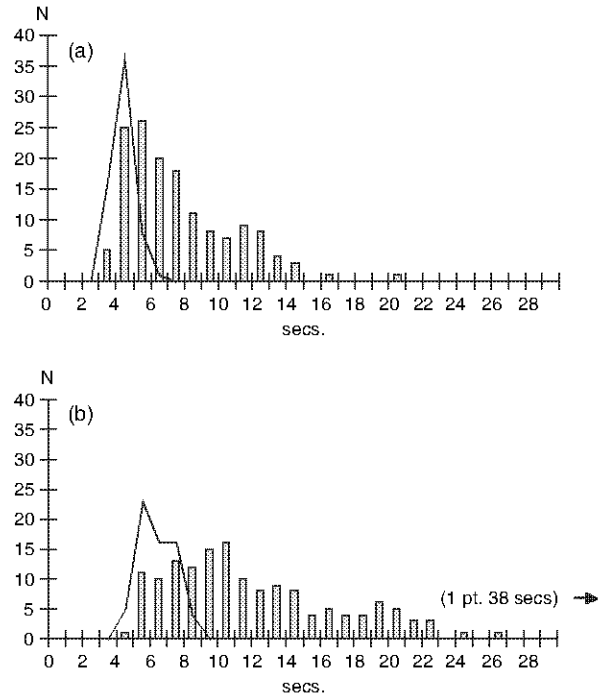


Figure 2 (a) The univariate distribution of the T25FW (s). The distribution in the control group is indicated with a line, while the number of MS patients in each time interval is indicated with a column. (b) The univariate distribution of the SSST (s). The distribution in the control group is indicated with a line, while the number of MS patients in each time interval is indicated with a column. Note that one patient is outside the range of the plot.

devices and scored significantly higher on the MSWS-12, EDSS and MSIS ($P < 0.05$). No significant effects were found for gender.

A total of 100 patients had abnormal T25FW values, ie, mean + 2 SD of the control population and 107 patients had abnormal SSST values, ie,

Table 1 Demographic properties and mean scores (SD) of all subjects

	<i>n</i>	T25FW (s)	SSST (s)	EDSS	MSIS	MSWS-12
All patients	151	7.1 (3.1)	11.0 (5.2)	3.8 (2.0)	28.3 (25)	29 (13)
Gender						
Male	45	7.1 (2.9)	11.0 (4.5)	4.3 (1.8)	28 (21)	31 (13)
Female	106	7.1 (3.1)	11.0 (5.2)	3.7 (2.1)	29 (26)	28 (13)
Age*						
20–40	75	6.0 (2.0)	9.1 (3.8)	3.0 (2.0)	20 (22)	25 (12)
41–80	76	8.3 (3.5)	13.0 (5.6)	4.7 (1.7)	38 (25)	33 (13)
Assistive device*						
None	94	5.7 (1.6)	8.8 (2.8)	2.9 (1.7)	19 (21)	25 (12)
One cane	31	10.0 (3.7)	15.4 (6.4)	5.7 (0.9)	49 (18)	39 (9)
Two canes	10	11.1 (2.5)	18.7 (3.3)	6.5 (0)	51 (21)	40 (12)
Walker	16	11.3 (2.4)	18.2 (3.2)	6.4 (0.2)	58 (12)	39 (14)

* $P < 0.05$ (ANOVA).

T25FW, Timed 25-Foot Walk; SSST, Six Spot Step Test; MSWS-12, 12-item Multiple Sclerosis Walking Scale; EDSS, Expanded Disability Status Scale; MSIS, Multiple Sclerosis Impairment Scale.

mean +2 SD of the control population. The difference in the rate of abnormality on the two tests was not statistically significant (McNemar). The use of the 97.5-percentile as cut-off value instead of mean +2 SD did not change the result.

The relationships between the ambulation tests and the EDSS were non-linear (Figure 3). Over the EDSS range 0–4.0, the mean SSST increased by 4.9 seconds, while the mean T25FW increased by only 2.1 seconds.

Both the T25FW and the SSST demonstrated excellent re-test reliability (r), 0.96 and 0.95, respectively (Table 2). We found no indication of a relevant practice effect.

The correlation between the two ambulation tests and the global impairment scales (EDSS, MSIS) was about 0.80 (Spearman's r). The strongest correlation was observed between the T25FW and SSST (r : 0.92). The MSWS-12 correlated moderately with all other variables (r : 0.69).

Discussion

The SSST is measured in the time domain similar to the T25FW. However, the time to perform the SSST depends more on co-ordination, balance and ease of abduction in the hip than the T25FW. Our results show that the range of measurement of the SSST, expressed as the 10- to 90-percentile range, is 68% wider than that of the T25FW, and that the floor effect of the SSST is less pronounced than that of the T25FW. As the re-test reliabilities of the two tests are equally good and the measurement error is the same, the sensitivity and discriminatory power of the SSST is better than that of the T25FW.

In the range 4.0–7.5, the EDSS measures ambulation on an ordinal scale, which combines walking distance and need of support [3–5]. This is in good agreement with the floor effect of the T25FW in the

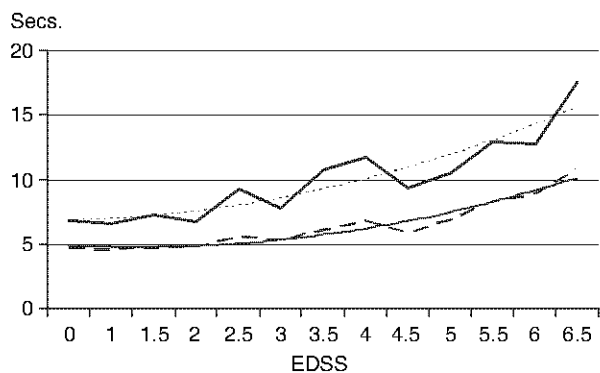


Figure 3 The mean values of the T25FW (broken line) and the SSST (full line) given as a function of the EDSS. The dotted lines are trend lines.

Table 2 Median values and percentiles of the SSST and T25FW in the total population, and median values of the first and second run in the retest population

	SSST	T25FW
<i>n</i> (total)	151	151
Median	10.7	6.9
10th percentile	6.6	4.5
90th percentile	19.7	12.3
<i>n</i> (retest)	41	41
Median 1 run	14.1	8.5
Median 2 run	14.1	8.2
ICC (r)	0.95	0.96

The retest reliability is given as the intraclass correlation (ICC).

EDSS range 0–4.0 and the steeper inclination in the EDSS range 4.5–6.5.

We found that the SSST was only moderately correlated to the EDSS and the MSIS, which indicates that the SSST and the quantitative neurological examinations for some part measure separate traits of MS.

The recently developed MSWS-12 [18], has been shown to have good reliability, validity and responsiveness. The MSWS-12 was only moderately correlated with T25FW, and the authors suggested walking speed is a limited indicator of patients' perception of their own walking ability. In our study, the MSWS-12 was moderately correlated to all the other study variables, thus confirming that the MSWS-12 measures other aspects of MS. However, it is remarkable that its correlation with specific ambulation tests, the T25FW and the SSST, is no better than with a global instrument as the MSIS. This may indicate that although the MSWS-12 is focused on ambulation, its nature as a self-rating scale makes it convey traits other than ambulation into the score. In other words, the patient's evaluation of his general condition may influence the self-rating of ambulation. In our study, several patients had difficulties completing the questionnaire, which were mostly caused by the fact that their lower limb function had been fluctuating over the past two weeks.

The MSFC has become widely used in clinical trials in MS. However, its present ambulation component is sub-optimal and a more complex ambulation test may increase the sensitivity and responsiveness of the composite. The SSST is an obvious alternative to the T25FW. The SSST is measured on a nominal scale, it is cost-effective and practical, and it is conceptually parallel to the 9-HPT. The responsiveness of the SSST is presently under investigation. The scaling properties of the SSST and the T25FW should be explored in clinical MS trials in which the MSFC is used as outcome measure.

References

1. **Kurtzke JF.** Rating neurologic impairment in multiple sclerosis: an expanded disability status scale (EDSS). *Neurology* 1983; **33**: 1444–52.
2. **Amato MP, Fratiglioni L, Groppi C, Siracusa G, Amaducci L.** Interrater reliability in assessing functional systems and disability on the Kurtzke scale in multiple sclerosis. *Arch Neurol* 1988; **45**: 746–48.
3. **Noseworthy JH, Vandervoort MK, Wong CJ, Ebers GC and the Canadian Cooperative MS Study Group.** Interrater variability with Expanded Disability Status Scale (EDSS) and Functional Systems (FS) in a multiple sclerosis clinical trial. *Neurology* 1990; **40**: 971–75.
4. **Whitaker JN, McFarland HF, Rudge P, Reingold SC.** Outcomes assessments in multiple sclerosis clinical trials: a critical analysis. *Mult Scler* 1995; **1**: 37–46.
5. **Hobart JH, Freeman J, Thompson AJ.** Kurtzke scales revisited: the application of psychometric methods to clinical intuition. *Brain* 2000; **123**: 1027–40.
6. **Rudick R, Antel J, Confranceux C, Cutter G, Ellison G, Fischer J et al.** Recommendations from the National Multiple Sclerosis Society clinical outcomes assessment task force. *Ann Neurol* 1997; **42**: 397–82.
7. **Cutter GR, Baier ML, Rudick RA.** Development of a multiple sclerosis functional composite (MSFC) as a clinical trial outcome measure. *Brain* 1999; **122**: 871–82.
8. **Rudick RA, Cutter GR.** Use of the multiple sclerosis functional composite (MSFC) to predict disability in relapsing MS. *Neurology* 2001; **56**: 1324–30.
9. **Rudick RA, Cutter GR, Reingold S.** The multiple sclerosis functional composite (MSFC): a new clinical outcome measure for multiple sclerosis. *Mult Scler* 2002; **8**: 359–65.
10. **Miller DM, Rudick RA.** Clinical significance of the multiple sclerosis functional composite (MSFC): relationship to patient-reported quality of life. *Arch Neurol* 2000; **57**: 1319–24.
11. **Kalkers NF, Groot de V.** Multiple sclerosis functional composite (MSFC): relation to disease phenotype and disability strata. *Neurology* 2000; **54**: 1233–39.
12. **Cohen JA, Fischer JS, Cutter GR.** Intrarater and interrater reliability of the multiple sclerosis functional composite (MSFC) outcome measure. *Neurology* 2000; **54**: 802–806.
13. **Cohen JA, Cutter GR, Fischer JS, Goodman AD.** Benefit of interferon B-1a on multiple sclerosis functional composite (MSFC) progression in secondary progressive MS. *Neurology* 2002; **59**: 679–87.
14. **Hoogervorst ELJ, Kalkers NF, Uitdehaag BMJ, Polman CH.** A study validating changes in the multiple sclerosis functional composite (MSFC). *Arch Neurol* 2002; **59**: 113–16.
15. **Cohen JA, Cutter GR.** Use of the multiple sclerosis functional composite (MSFC) as an outcome measure in a phase-3 clinical trial. *Arch Neurol* 2001; **58**: 961–67.
16. **Fischer JS, Rudick RA, Cutter GR.** The multiple sclerosis functional composite (MSFC) measure: an integrated approach to MS clinical outcome assessment. *Mult Scler* 1999; **5**: 244–50.
17. **Kalkers NF, Bergers L.** Concurrent validity of the multiple sclerosis functional composite (MSFC) using MRI as a biological marker. *Neurology* 2001; **56**: 215–19.
18. **Hobart JC, Riazi A, Lamping DL, Fitzpatrick R, Thompson AJ.** Measuring the impact of MS on walking ability: the 12-item MS Walking Scale (MSWS-12). *Neurology* 2003; **60**: 31–36.
19. **Ravnborg M, Grønbech-Jensen M, Jønsson A.** The MS-impairment scale: a pragmatic approach to the assessment of impairment in patients with multiple sclerosis. *Mult Scler* 1997; **3**(1): 31–42.
20. **Ravnborg M, Blinkenberg M, Sellebjerg F, Ballegaard M, Larsen SH, Sorensen PS.** Responsiveness of the Multiple Sclerosis Impairment Scale in comparison with the Expanded Disability Status Scale. *Mult Scler* 2005; **11**(1): 81–84.

Appendix

Administration and scoring manual of the SSST

Description SSST

Similar to the T25FW, the SSST is a quantitative measure of lower extremity function. The test contains a rectangular field with six circles on the floor following a criss-cross course. Five circles contain a block. The starting-point is the first circle, which does not contain a block. From there the patient walks to the other side of the field and kicks the blocks out of the five circles, as quickly as possible. The task is immediately administered again by having the patient walk back the same route. Both the dominant and non-dominant legs are tested twice.

Materials needed

Wooden cylinder-blocks (8 × 4 cm (diameter × height), weight 140 g), chalk to draw circles (diameter 20 cm), stopwatch, clipboard, marked field, SSST record form.

Discontinue rules

1. If the patient cannot complete the other trials after Trial 1 with the dominant leg and a 5-minute rest period.
2. If the patient cannot successfully complete one trial in two consecutive attempts.
3. If the patient cannot complete a trial with his or her dominant leg within 3 minutes, move on to the trials with the non-dominant leg.

Administration

Dominant leg Trial 1

All six circles have to be clearly marked on the floor with chalk and the blocks have to be correctly placed in the circles according to Figure 1. If this is the first visit, the patient is asked which is their dominant leg. The patient should be informed how the SSST works and instructed to stand on the first circle. Afterwards the patient has to be instructed in the following way: 'I'd like you to walk to the other side of the field as quickly as possible, while kicking the blocks out of the circles with the side of your foot of your dominant leg only. Ready? Go.' Begin timing when the patient leaves the first circle. The examiner should walk along with the patient as he/she completes the task. Stop timing when the patient kicks the last block out of the circle. The examiner should then record the patient's walk time to within 0.1 second, rounding as needed.

Dominant leg Trial 2

After completing the first timed walk, replace the blocks and position the patient on the first circle again. Repeat the same instructions, and have the patient complete the walk again.

Non-dominant leg Trials 1 and 2

After the second timed walk with the dominant leg, replace the blocks and position the patient on the first circle again. Then say, 'Now I'd like you to do the same again while using the foot of your non-dominant leg only to kick the blocks out of the circles. Ready? Go' Administer, time, and record the two non-dominant leg trials following the procedure described above for dominant leg trials.

Assistive devices

If necessary the patient should use their customary assistive device for outside walking. If a patient does use an assistive device, this should be noted on the record form.

Remarks

The trial has to be restarted after a maximum resting time of 2 minutes if:

- the patient drops or loses the assistive device
- the patient falls, is not injured and able to continue