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ORIGINAL ARTICLE

Validity and reliability of the 10-m walk test and the 6-min walk test in spinal cord injury patients

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Study design: The 10-m walk test (10MWT) and the 6-min walk test (6MWT) have been recommended for assessment of walking in spinal cord injury (SCI) patients. The study was designed on test–retest analysis of the 10MWT and 6MWT.
Objectives: The objective of this study was to assess validity/reliability of different methods of performing the tests.
Setting: The study was set at an SCI unit of a rehabilitation hospital.
Patients and methods: A total of 37 patients; whose median age was 58.5 years (interquartile range 40–66, full range 19–77); median time since onset of SCI was 24 months (interquartile range 16.25–70.5, full range 6–109). Non-traumatic etiology in 20 out of 37 patients; level: 12C, 14T and 11L; American Spinal Injury Association Impairment Scale grade: 35D/2C. Assessment with the 10MWT (with or without dynamic start) and the 6MWT (short or long track) by two blinded raters to evaluate inter/intra-rater reliabilities.
Results: The 10MWT was performed in a median of 19 s (25th–75th interquartile range 13–28) with the dynamic start and of 18.4 s (25th–75th interquartile range 12.6–29.9) with the static start ($P = 0.092$). The correlation between the results of the two methods was between 0.98 and 0.99. The inter- and intra-rater reliabilities were between 0.95 and 0.99 for both the methods. The 6MWT showed significant differences according to the track length: patients walked a median of 226.7 m (25th–75th interquartile range 123.2–319) on the longer track and of 187.6 m (25th–75th interquartile range 69.7–240.6) on the short one ($P < 0.001$). The correlation between the results of the two methods was between 0.91 and 0.93. The inter- and intra-rater reliabilities were between 0.98 and 0.99.
Conclusion: The 10MWT shows high inter/intra-rater reliability and shows comparable results with both dynamic and static start. The different testing conditions of the 6MWT (track/turns) results in significant differences that need standardization for use in future trials.
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Keywords: spinal cord injury; walking; 10-m walk test; 6-min walk test; WISCI

Introduction

Epidemiological studies show that 44.4% or more of the patients with spinal cord injury (SCI) suffer an incomplete lesion (for example, with sensory and/or motor preservation below the lesion level).[1,2] Depending on the severity of the incomplete lesion, most patients will have the potential to recover walking function.[2] Walking recovery is one of the main goals of patients after a spinal cord lesion; indeed, walking is rated as the most important goal by patients with incomplete lesions.[3] Therefore, the recovery of ambulation has become the target of several pharmacological and rehabilitative approaches[4] and a precise evaluation of ambulation in these patients has become mandatory.

Although several walking measures have been suggested for assessment of walking function in patients with SCI, over the past 5 years most studies have focused on the 10-m walk test (10MWT),[5–14] the 6-min walk test (6MWT)[5–10,13,15] and the Walking Index for Spinal Cord Injury (WISCI).[5,7,9,12,14,16–20] This set of measures allows a comprehensive assessment of walking function, which includes the use of walking aids, braces, physical assistance, and speed and endurance.

Both the 10MWT and the 6MWT have been utilized in studies of SCI patients.[5–16] Both tests showed good inter- and intra-rater reliabilities,[5] a good relationship with lower limbs strength[17] and with other walking tests (the WISCI and the

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'timed up and go').[5] Furthermore, both tests seem to have a greater sensitivity to detect changes of performance in less severely injured SCI patients if compared with the WISCI, which has a ceiling effect.[7,9] On the basis of these considerations, in 2006, at the National Institute for Disability and Rehabilitation Research Outcome Measures Meeting in Boston, MA, USA, the Conference Subcommittee on Gait and Ambulation recommended a battery of tests, including the WISCI, the 10MWT and the 6MWT as outcome measures for gait in SCI.[21] More recently the Spinal Cord Outcomes Partnership Endeavour group made similar recommendations.[22] In both the cases, further validation studies of the three tests, especially for the 6MWT, have been recommended. With regard to the 10MWT, although a distance of 10 m is the most widely used method in neurological patients to assess speed, in about half of the manuscripts a static start was used rather than a dynamic one.[23] Although the 10MWT with a dynamic (flying) start has been validated as an assessment of speed in a number of acute SCI studies,[5–7] the static start for 10 m used in the WISCI assessment has shown reliability and repeatability[20] for speed in chronic SCI subjects.

The 6MWT presents a problem of standardization in our opinion. In fact, the American Thoracic Society, which originally standardized the test for use in patients with pulmonary diseases, recommended that the test be performed on '…a long, flat, straight, enclosed corridor with a hard surface that is seldom traveled. The walking course must be 30 m in length…'.[24] The test, however, has been performed with a variety of track shape and distances for neurological disorders other than SCI.[25–28] The distance of the track varied from 85 m,[25] 39 m[26] to 20-m corridors with 180° turns[28] for several studies on stroke subjects. A few studies of SCI defined distances and turns, which varied from non-standardized hallways of 50 feet or more with 90° turns[8] to 53 (reviewed in Olmos *et al.*[10]) and 60 m,[13] with 90° turns and different surfaces. Several other studies in SCI by the same authors did not identify either the shape of the track or the frequency of turns.[5,7,8,15]

Therefore, we propose to test the following hypotheses:

10MWT

(a) The 10MWT has comparable results if performed with and without the dynamic start and the results of the two methods are highly correlated;
(b) The evaluation of speed for a 10-m distance has good inter- and intra-rater reliabilities if performed with a static start.

6MWT

(a) The results of the 6MWT depend on the length of the track (that is, the number of turns).

Patients and methods

We studied subjects with subacute or chronic, incomplete SCI of traumatic and non-traumatic etiology. Patients included in the study were required to have functional ambulation at home and in the community, could walk with or without braces/orthosis and not confined to a wheelchair.

Exclusion criteria were the presence of cognitive deficits or other diseases, especially cardiac and lung diseases, which could limit patient's effort.

The study was approved by the local Ethical Committee and all the patients gave their informed consent.

For all the patients we recorded the following data:

- Demographic data: gender, age, time from onset of the lesion and etiology of lesion.
- Neurological status, assessed using the American Spinal Injury Association standards,[29] with documentation of the American Spinal Injury Association standards Impairment Scale, total motor score and lower extremity motor score.
- Usual walking level according to the WISCI II.[16]

All patients underwent the following walking measures:

- 10MWT[30]: in the 10MWT the time required to walk 10 m is measured by use of a stop watch. Subjects walk in a straight line. The test was performed in two conditions: (1) with a dynamic (flying) start to allow 2-m acceleration, a timed 10-m distance and 2-m deceleration; and (2) with a static start with a timed 10-m distance during levels 2 to 20 of the WISCI examination.[20]
- 6MWT[24] the 6MWT is a measure of distance and represents the maximum distance walked in 6 m. This test was performed in two conditions too: (1) on a rectangular, 10×50 m, indoor track; and (2) on a short, 10-m track on which the patients walked back and forth. The 10×50 m track was chosen to compare the longer distance with the short 10-m track, because the WISCI scale's validation and reliabity has been tested on a 10-m track.[20,18,19] The 30-m track had been validated for patients with respiratory/cardiovascular subjects, and permitted rest periods because of cardiac precautions,[24] and was determined not suitable for our study population. Longer track distances between 50 and 60 m had been utilized in recent studies of SCI subjects.[10,13] Patients were asked to walk at a self-selected speed, but without resting. They were asked to walk at the WISCI level they used in the community (usual WISCI level) in regard to the use of devices (braces/walking aids) and physical assistance.

Both the tests were evaluated by two different blinded raters and repeated after a 48–72 h interval to assess inter- and intra-rater reliabilities. The test–retest interval of 48–72 h is based on the protocol used in the collaborative study reported 2010 (reviewed in Marino *et al.*[20]).

Statistical analysis

All statistical analyses were performed with SPSS statistical software for Windows (version 12.0, Chicago, IL, USA). Descriptive statistics were calculated for all variables as median and interquartile range, as well as the full range. Normality of variables was checked with Kolgomorov–Smirnoff normality test. According to this test, all the evaluated measures are not normally distributed, so the

Wilcoxon signed–rank test was used to assess differences between the various modalities. To assess the correlation between the results of the different methodologies and the inter- and intra-rater reliabilities, the intraclass correlation coefficient was used. Results were considered statistically significant if $P<0.05$.

Results

We studied 37 patients (28 men and 9 women) (Table 1); median age was 58.5 years (interquartile range 40–66, full range 19–77); median time since onset of SCI was 24 months (interquartile range 16.25–70.5, full range 6–109). Most patients had a lesion of non-traumatic etiology (20 out of 37). With regard to lesion level 12 patients had a lesion at the cervical level, 14 at the thoracic level and 11 at the lumbar level. All patients but two had an American Spinal Injury Association standards Impairment Scale (D); two patients had an American Spinal Injury Association standards Impairment Scale (C) and a lesion at lumbar level and walked with an ankle-foot orthosis. WISCI median was 16 (interquartile range 13–19, full range 9–20). Mean motor score was 88 ± 7.

The 10MWT was performed in a median of 19 s (25th–75th interquartile range 13–28), with the static start and in a median of 18.4 s (25th–75th interquartile range 12.6–29.9) with the dynamic start ($P=0.092$). When examining the patients according to either high or low WISCI level, the results for static and dynamic starts were comparable. Patients ($N=15$) with high WISCI levels (18–20) performed the test in a median of 13.17 s (25th–75th interquartile range 10.8–19) with the static start and a median of 12.7 s (25th–75th interquartile range 10–18.5) with the dynamic one ($P=0.17$). Patients ($N=6$) with low WISCI levels (9–12) performed the test in a median of 19.8 s (25th–75th interquartile range 15–32.3) with the static start and a median of 19.8 s (25th–75th interquartile range 14.6–30.9) with the dynamic one ($P=0.46$). The correlation between the results of the two methods was between 0.98 and 0.99 (Table 2). The inter-rater reliability was between 0.95 and 0.98 for both the methods. The intra-rater reliability was between 0.98 and 0.99 (Table 3).

The 6MWT showed significant differences according to the track length: patients walked a median of 226.7 m (25th–75th interquartile range 123.2–319) on the longer track (50 m) and a median of 187.6 m (25th–75th interquartile range 69.7–240.6) on the short one (10 m) ($P<0.001$). The correlation between the results of the two methods was between 0.91 and 0.93 (Table 4). The inter-rater reliability was between 0.99 and 1. The intra-rater reliability was between 0.98 and 0.99 (Table 5).

Table 1 Patients' features

Patients	*Sex*	*Age*	*Time from lesion to the test (months)*	*Etiology*	*Level*	*AIS*	*WISCI*
1	F	68	28	NT	T5	D	13
2	F	60	6	NT	C7	D	20
3	M	19	24	T	L3	D	19
4	F	38	24	T	L1	D	9
5	M	36	72	T	L2	D	11
6	M	66	48	T	T6	D	16
7	F	31	18	T	C5	D	15
8	M	59	72	NT	T7	D	13
9	M	37	48	T	T12	D	12
10	M	28	24	T	C3	D	20
11	M	48	72	T	L2	D	20
12	F	53	9	NT	T10	D	19
13	M	46	17	T	L3	C	9
14	M	34	12	T	C6	D	9
15	M	75	48	NT	L2	D	16
16	M	60	10	T	C6	D	20
17	M	65	15	NT	C4	D	20
18	M	68	66	NT	T12	D	13
19	M	24	11	T	L3	C	13
20	M	57	22	T	L4	D	16
21	M	63	21	NT	T12	D	20
22	M	52	16	NT	T12	D	19
23	F	58	48	NT	T5	D	14
24	F	74	17	NT	T6	D	19
25	M	65	8	NT	T7	D	20
26	M	66	96	NT	C6	D	19
27	F	72	102	NT	T7	D	13
28	M	31	108	T	L2	D	16
29	F	66	73	NT	T12	D	18
30	M	69	84	NT	C5	D	12
31	M	50	19	T	L3	D	13
32	M	66	24	NT	C7	D	19
33	M	58	109	NT	C7	D	16
34	M	70	24	NT	C6	D	13
35	M	69	19	NT	T3	D	20
36	M	68	47	T	C5	D	16
37	M	49	13	T	L2	D	16

Abbreviations: AIS, American Spinal Injury Association Impairment Scale; F, female; M, male; WISCI, Walking Index for Spinal Cord Injury.

Table 2 Intraclass correlation coefficient between the two methodologies for the 10MWT

	ICC (95% CI)	P-*value*
Rater 1/day 1	0.98 (0.97–0.99)	<0.001
Rater 1/day 2	0.98 (0.93–0.99)	<0.001
Rater 2/day 1	0.99 (0.85–0.99	<0.001
Rater 2/day 2	0.99 (0.83–0.99)	<0.001

Abbreviations: 10MWT, 10-m walk test; CI, confidence interval; ICC, intraclass correlation coefficient.

Table 3 10MWT inter- and intra-rater reliabilities

	ICC	P-*value*
Inter-rater reliability		
Static start/day 1	0.98 (0.93–0.99)	<0.001
Static start/day 2	0.95 (0.82–0.98)	<0.001
Dynamic start/day 1	0.97 (0.90–0.99)	<0.001
Dynamic start/day 2	0.98 (0.95–0.99)	<0.001
Intra-rater reliability		
Static start/rater 1	0.99 (0.97–1)	<0.001
Static start/rater 2	0.99 (0.96–0.99)	<0.001
Dynamic start/rater 1	0.98 (0.93–0.99)	<0.001
Dynamic start/rater 2	0.99 (0.96–0.99)	<0.001

Abbreviations: 10MWT, 10-m walk test; CI, confidence interval; ICC, intraclass correlation coefficient.

Table 4 Intraclass correlation coefficient between the two methodologies for the 6MWT

	ICC	P-*value*
Rater 1/day 1	0.91 (−0.10 to 0.98)	<0.001
Rater 1/day 2	0.92 (−0.06 to 0.98)	<0.001
Rater 2/day 1	0.93 (−0.02 to 0.98)	<0.001
Rater 2/day 2	0.92 (−0.05 to 0.98)	<0.001

Abbreviations: 6MWT, 6-min walk test; CI, confidence interval; ICC, intraclass correlation coefficient.

Table 5 6MWT inter and intra-rater reliability

	ICC	P-*value*
Inter-rater reliability		
Long track/day 1	0.99 (0.98–0.99)	<0.001
Long track/day 2	0.99 (0.99–0.99)	<0.001
Short track/day 1	0.99 (0.98–0.99)	<0.001
Short track/day 2	0.99 (0.99–0.99)	<0.001
Intra-rater reliability		
Long track/rater 1	0.99 (0.97–0.99)	<0.001
Long track/rater 2	0.99 (0.98–0.99)	<0.001
Short track/rater 1	0.99 (0.94–0.99)	<0.001
Short track/rater 2	0.99 (0.97–0.99	<0.001

Abbreviations: 6MWT, 6-min walk test; CI, confidence interval; ICC, intraclass correlation coefficient; NT, nontraumatic; T, traumatic.

Discussion

The results of the present study addressed several problems in regard to the preferred method for performing the 10MWT and the 6MWT for use in clinical trials. With regard to the 10MWT the question raised was whether the test should be performed with a dynamic or a static start.[23] The two methodologies provided comparable results in our subjects. Although patients needed less time while performing the test with a dynamic start, this difference was not statistically significant. The results of the two different methods were strongly correlated and both tests showed high intra- and inter-rater reliabilities.

A comparable level of agreement was demonstrated with a dynamic (flying) start by van Hedel[5] in SCI patients and by Rossier[30] in chronic neurological lesions. However, it is possible that some subjects who have very mild lesions and recover rapidly achieving normal walking speeds such as $2\,m\,sec^{-1}$ (reviewed in van Hedel *et al.*[6]), may demonstrate a greater difference based on a dynamic start, but this was not true in a subset of our subjects who walked at WISCI levels of 18–20.

The strong relationship between the results of the two methods suggest that the speed on the 10-m walk could be validly and reliably assessed with a static start and distance of 10 m, and does not require the additional distance of 4 m with a dynamic start. The static start method has been already recommended by Graham.[23] Furthermore, this way of assessing speed would allow the combination of the 10MWT and the WISCI to be performed simultaneously. As levels 2–20 of the WISCI method are based on a static start of 10-m length, and the repeatability of the time to walk this distance has been reported by Marino.[20] In chronic subjects with SCI, combining the two measures would save time and could be considered for use in clinical trials. If this method were applied to studies of acute SCI subjects, only a 10-m walking distance from a static start would be required compared with the 14-m walking distance of the dynamic start, potentially decreasing the floor effect of four additional meters at baseline. It is possible that more severely paralyzed patients could be entered for walking speed at the time of the baseline WISCI assessment, which has not been possible in previous studies.[4,6]

With regard to the 6MWT, the data of our study clearly demonstrates that the results of the 6MWT depend on the way the test is performed. On the longer track of 50 m, the patients walked for a distance five times longer before turning than on the shorter track of 10-m distance. As stated above, despite the instructions of the American Thoracic Society, the 6MWT has been performed on tracks of different shapes and different lengths before turning. The choice of the shape and of length often depends on the availability of space in the different facilities where the test is used. In 2003, it was demonstrated that, in patients with severe asthma, the results of the test differ depending on the shape of the path (straight or continuous) more than the length of the path itself.[31] Similar data have been shown for stroke patients[28] and the authors suggested that the results were influenced by the number of turns made by that patients. In the present study, it is difficult to decide whether the difference in the distance walked is because of a different shape (as the short track required the patients to turn 180° and the long one to 90° turns), the frequency of turns or both factors.

Although the report of the conference on outcome measures[21] recommended further work on the 6MWT, which stimulated our study, recent publications[6,15] suggest that short distance speed of walking is adequate for a clinical trial. In light of our findings and the need to consider longer distances in chronic subjects and follow-up longer than 6 months, standardization may result in sharper responsiveness to change. The present study has several limitations that should ideally be addressed in future researches. Ideally the test–retest period should have been 2 weeks rather than 24–72 h to avoid recall bias and should be addressed in future studies. The study represents a single-center experience and needs to be replicated in a multicenter study. Finally, a comparison of walking speed from a dynamic and static start should be studied in a cohort of acute SCI patients.

Conclusion

This study demonstrates that the 10MWT shows high inter- and intra-rater reliabilities and shows comparable results with both the dynamic and static start. Therefore, based on our findings and a recent study,[20] which combined simultaneous assessments of static start 10MWT and WISCI performed in chronic SCI, the requirement of testing speed twice would be eliminated. With regard to the 6MWT, our data shows that the different testing condition of the track

and turns results in significant differences that need to be standardized for use in future trials.

Conflict of interest

The authors declare no conflict of interest.

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