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Original Article

Improving walking assessment in subjects with an incomplete spinal cord injury: responsiveness

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Study design: Prospective longitudinal study.
Objectives: To investigate the responsiveness of the Walking Index for Spinal Cord Injury II (WISCI II), 6-Min Walk (6MWT) and 10-Meter Walk Tests (10MWT) for the assessment of walking capacity in incomplete spinal cord injury (iSCI) and to validate these tests with the lower extremity motor score (LEMS).
Setting: European Multicenter Study of Human Spinal Cord Injury.
Methods: The walking tests of 22 iSCI subjects who achieved functional ambulation and could stand or walk within 1 month after iSCI were analyzed at 3, 6 and 12 months after injury. Responsiveness was assessed by determining differences between the time intervals, and Spearman's correlation coefficient was calculated to quantify validity.
Results: All walking tests were able to assess the improvement of walking capacity within the first 3 months after injury. Between 3 and 6 months, only the 10MWT and 6MWT were responsive to the ongoing improvement in locomotor capacity. Overall, correlations between the tests were good within the first month, but became poorer over time.
Conclusion: The 6MWT and 10MWT were more responsive in demonstrating an improvement in walking capacity compared to the WISCI II. The testing of functional outcome after iSCI as provided by the ordinal ASIA motor score can be improved by interval scaled measures. This allows increasing the responsiveness of functional outcome measures and should be advantageous in assessing therapeutical approaches in iSCI subjects. In iSCI subjects with walking ability, we recommend the additional use of timed tests to monitor improvement in locomotor capacity.
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Keywords: ASIA; lower extremity motor score; timed walking tests; assessment; validity

Introduction

The assessment of the recovery of walking capacity is an important issue in the rehabilitation of patients afflicted by spinal cord injury (SCI); both for the evaluation and comparison of established and new therapeutical approaches. It is therefore important that valid, reliable and responsive measurement tools are applied to assess changes in the functional ability in SCI subjects.

In the present study, we were interested how well several walking tests could detect changes in walking capacity. Capacity describes an individual's ability to execute a task or an action and aims to indicate the highest probable level of functioning that a person may reach in a given domain at a given time.[1] An improvement in walking capacity should not necessarily be quantified by an increase in walking speed, but also, for example, in the reduced need of a patient to depend on walking aids or external assistance. Indeed, the recently introduced Walking Index for Spinal Cord Injury II (WISCI II)[2,3] is assumed to be an excellent tool to assess the patient's need for assistance or helping aids during walking. A recent retrospective study showed that the WISCI II was more responsive in detecting changes in locomotor ability in patients with a SCI compared to other tests.[4] These tests were the Barthel Index (mobility items),[5] Rivermead Mobility Index,[6] locomotor items of the Functional Independence Measure[7] and the indoor mobility scores of the Spinal Cord Independence Measure.[8,9] The limitation of all of these tests is that they comprise of ordinal scales with unequal distances between individual categories. Therefore, these tests seem to be limited to detecting changes

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in locomotor ability compared to tests that are comprised of an interval scale. Indeed, Morganti et al[4] found that within three WISCI II categories (13 (walker, no braces or assistance), 16 (two crutches, no braces or assistance) and 20 (no devices or assistance)) the LEMS and other walking features varied considerably. The authors suggested that the WISCI II would benefit from further refinement based on, for example, speed.

The reliability and validity of the 6-Min Walk Test (6MWT), the 10-Meter Walk Test (10MWT) and the Timed Up and Go Test (TUG) has been investigated recently in subjects with SCI.[10] The 6MWT measures the distance walked during 6 min, while the 10MWT measures the time needed to walk 10 m. The 10MWT is performed with 'flying start,' that is, while the subject walks about 14 m, the time is measured for walking the intermediate 10 m. The TUG assesses the time needed to stand up from a chair, walk 3 m, turn around, walk back and sit down again. These tests were performed at preferred walking speed.[10] Overall, the WISCI II correlated well with these timed walking tests. However, in subjects with severely impaired walking ability, the WISCI II correlated poorly with the timed tests.

The goal of the present study was to assess the responsiveness of the 6MWT and 10MWT compared to the WISCI II in subjects with an incomplete SCI (iSCI) and who have achieved some walking capacity already in the early stages after injury. As these patients show most extensive improvements in walking capacity, they are considered appropriate subjects for studying the responsiveness of walking tests. In addition, we assessed the lower extremity motor score (LEMS), which was assessed according to the American Spinal Injury Association (ASIA)[11] for construct validation, as Morganti et al[4] did. The LEMS is a measure of motor recovery and reflects the level of injury and neurological recovery. By comparing the LEMS with the walking tests, we could determine the relationship between the level of neurological recovery and the walking capacity as assessed with the WISCI II, 10MWT and 6MWT.

Methods

The LEMS and the three walking tests (WISCI II, 6MWT and 10MWT) were prospectively assessed at four time intervals after iSCI: within the first month and at 3, 6 and 12 months. The data were derived from the European Multicenter Study of Human Spinal Cord Injury (EM-SCI) database which presently contains 407 complete and incomplete SCI patients.[12] Only incomplete patients who were able to stand or walk within the first month after SCI were selected for this study (WISCI II score $\geqslant 1$; $n = 75$). In addition, they should have performed the 6MWT and 10MWT at all four times. According to these criteria, 22 iSCI subjects were included. The average age was 45.5 years (SD = 16.7; range: 17–78). More detailed characteristics of the iSCI subjects are presented in Table 1. The timed walking tests were performed at preferred speed. We certify that all applicable institutional and governmental regulations concerning the ethical use of human volunteers were followed during the course of this research.

Table 1 Characteristics of incomplete spinal cord injured subjects

ID	*Cause of injury*	*Level of lesion*	*Sex*	*Age*	*LEMS ⩽ first month*	*LEMS at 12 months*
1	T	L1	F	32	28	41
2	T	C4	M	35	20	49
3	T	C4	M	74	43	48
4	T	L2	M	29	41	46
5	T	C5	M	54	50	50
6	T	S1	M	51	50	50
7	T	C5	F	78	48	50
8	N	L4	F	59	43	47
9	T	L2	F	23	30	40
10	T	C6	M	51	44	45
11	T	Th8	M	17	44	42
12	T	C6	M	46	48	50
13	N	C4	M	40	38	50
14	T	C5	M	19	23	48
15	T	C5	M	71	50	50
16	T	L1	M	36	33	48
17	T	L2	M	42	31	37
18	T	C5	M	63	26	40
19	N	C5	M	47	32	44
20	T	C5	M	45	28	49
21	T	L5	M	42	47	49
22	T	C2	M	49	48	50

ID, identification; LEMS, lower extremity motor score; T, traumatic; N, non-traumatic; C, cervical; Th, thoracic; L, lumbar; S, sacral; F, female; M, male

Statistics

Due to the relatively small number of subjects and the distribution of the data, statistical differences were tested using the nonparametric Friedman's test ($\alpha = 0.05$). Pair-wise comparisons were performed using Wilcoxon's signed rank test to determine differences between successive time intervals. For these pair-wise comparisons, α was corrected for multiple comparisons (maximal 2) and set at $0.05/2 = 0.025$. To quantify validity, Spearman's correlation coefficients were calculated between the four tests at the four time intervals.

Results

Figures 1 and 2 show the longitudinal data. The Friedman's test showed significant differences between the four time intervals for LEMS ($DF = 3$, $F_r = 34.9$; $P < 0.001$), WISCI II ($DF = 3$, $F_r = 28.7$; $P < 0.001$), 6MWT ($DF = 3$, $F_r = 38.9$; $P < 0.001$) and 10MWT ($DF = 3$, $F_r = 41.4$; $P < 0.001$). The LEMS differed between time intervals 1 and 2 ($P < 0.001$; Figure 1a). The differences between time intervals 2 and 3 ($P = 0.06$) and 3 and 4 ($P = 0.43$) were not significant. Similarly, the WISCI II differed between time interval 1 and 2 ($P = 0.005$), but not between 2 and 3 ($P = 0.18$) or 3 and

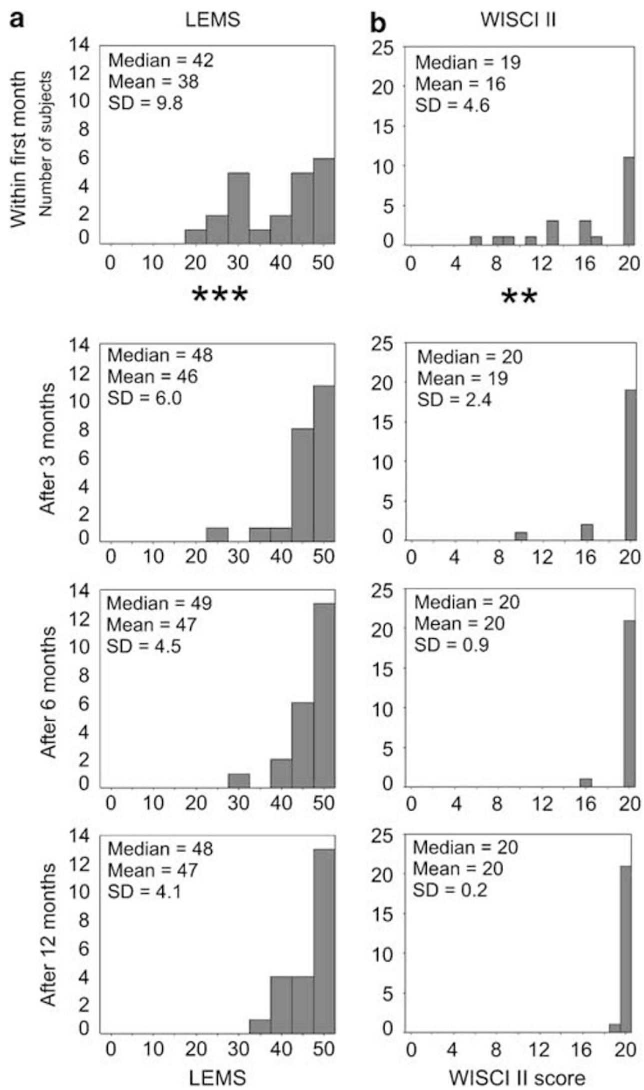

Figure 1 Changes in LEMS and WISCI II during recovery. Shown are the results of the (**a**) LEMS and (**b**) WISCI II performed within the first month after incomplete spinal cord injury and after 3, 6 and 12 months of 22 subjects. In the histograms, the number of subjects is presented on the y-axis, while the results for the tests are presented on the x-axis. Note that the width of the classes is 5 points for the LEMS and 1 point for the WISCI II. The width was chosen arbitrarily to present the data more clearly. Abbreviations: LEMS, lower extremity motor score; WISCI II, Walking Index for Spinal Cord Injury II. $^{**}P \leqslant 0.01$; $^{***}P \leqslant 0.001$

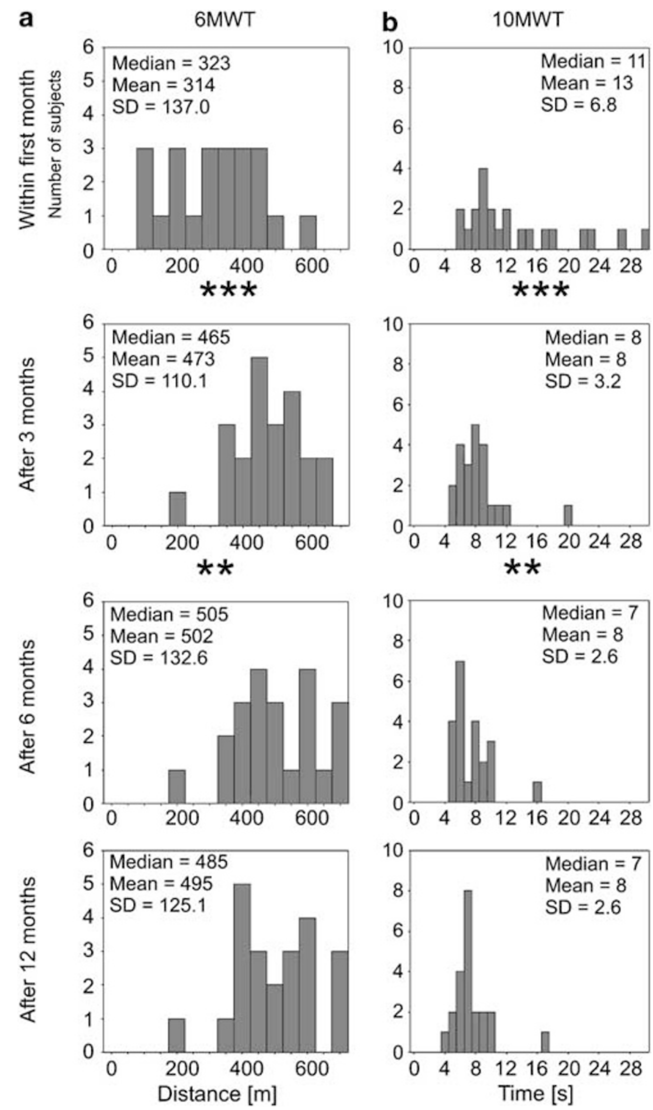

Figure 2 Changes in timed walking tests during recovery. Shown are the results of the (**a**) 6MWT and (**b**) 10MWT performed within the first month after incomplete spinal cord injury and after 3, 6 and 12 months of 22 subjects. In the histograms, the number of subjects is presented on the y-axis, while the results for the tests are presented on the x-axis. Note that the width of the classes is 50 meters for the 6MWT and 1 s for the 10MWT. The width was chosen arbitrarily to present the data more clearly. Abbreviations: 6MWT, 6-Min Walk Test; 10MWT, 10-Meter Walk Test. $^{**}P \leqslant 0.01$; $^{***}P \leqslant 0.001$

4 ($P = 0.31$; Figure 1b). The 6MWT differed between time intervals 1 and 2 ($P < 0.001$) and 2 and 3 ($P = 0.01$), but not between 3 and 4 ($P = 0.76$; Figure 2a). Finally, the 10MWT differed between time intervals 1 and 2 ($P < 0.001$) and 2 and 3 ($P = 0.005$), but not between 3 and 4 ($P = 0.91$; Figure 2b).

Table 2 shows the Spearman correlation coefficients and P-values calculated between the several tests at each time interval. Independent from time interval, the correlations between 6MWT and 10MWT remain excellent.[13] Within the first month, most correlations are good to excellent. After 3 months, the correlation between LEMS and WISCI II is still good, while the other correlations are only little to fair. The LEMS correlates well with the 6MWT after 6 and 12 months after SCI, while the other correlations remain fair.

Discussion

The main aim of the present study was to assess the responsiveness of the timed walking tests and the WISCI II and LEMS in subjects with iSCI. The present study

Table 2 Correlations between the tests at four different time intervals after iSCI

	WISCI II	*6MWT*	*10MWT*
Within 1 month			
LEMS	**0.49**	**0.54**	**−0.45**
	0.02	*0.01*	*0.04*
WISCI II		**0.78**	**−0.79**
		<0.001	*<0.001*
6MWT			**−0.91**
			<0.001
After 3 months			
LEMS	**0.50**	0.34	−0.30
	0.02	*0.12*	*0.18*
WISCI II		0.28	−0.21
		0.20	*0.35*
6MWT			**−0.90**
			<0.001
After 6 months			
LEMS	0.38	**0.49**	−0.40
	0.08	*0.02*	*0.06*
WISCI II		0.36	−0.37
		0.10	*0.09*
6MWT			**−0.87**
			<0.001
After 12 months			
LEMS	0.32	**0.55**	−0.39
	0.15	*<0.01*	*0.07*
WISCI II		0.36	−0.37
		0.10	*0.09*
6MWT			**−0.86**
			<0.001

iSCI, incomplete spinal cord injury; LEMS, lower extremity motor score; WISCI II, Walking Index for Spinal Cord Injury II, 6MWT, 6-Min Walk Test; 10MWT, 10-Meter Walk Test. Shown are Spearman's correlation coefficient (upper value) and the *P*-value (lower value; in italic). Significant correlations are in bold

reveals several important findings. Firstly, at lower levels of walking capacity all applied clinical scores are able to monitor changes in ambulatory function. Secondly, at higher levels of walking capacity only the 6MWT and 10MWT were sensitive enough to detect further improvement.

In the studied iSCI subjects, the LEMS showed a significant improvement in motor strength between the first and third month after injury and remained stable thereafter. This was in parallel to the changes in locomotor capacity as assessed with the WISCI II and the timed walking tests. However, between the third and sixth month after iSCI, only the 6MWT and 10MWT were able to show additional improvements in locomotor ability. It appears that in the present sample of less-limited walkers, the WISCI II is less responsive in assessing improvement in walking ability. The interval scaled timed walking tests detected improvements in locomotor capacity within almost one WISCI II category. All but one of the iSCI subjects qualified up to WISCI II score 20, which results in a ceiling effect. In conclusion, the timed walking tests were more responsive in assessing locomotor improvement and outcome compared to WISCI II. Clearly, the prediction of Morganti *et al*[4] that the WISCI II would profit from additional information about walking speed was confirmed in our study.

We used the LEMS to validate the walking tests in this sample of only moderately impaired walkers and to assess its responsiveness. Within the first month, the LEMS correlated fair to good with all walking tests. Apparently, at onset of the rehabilitation, leg muscle strength correlated well with walking ability in subjects with iSCI. Even 6 and 12 months after iSCI, the LEMS correlated well with the distance walked during 6 min.

However, the responsiveness of the LEMS was less compared to the timed walking tests. The LEMS changed significantly within the first 3 months, while the timed walking tests were responsive to changes in walking capacity for up to 6 months. Several reasons could account for this. Firstly, the LEMS is a summation of ordinal scores of each tested muscle, which could be less responsive at detecting changes in motor function over time. In the moderately impaired subjects in the present study, this resulted in a ceiling effect of the LEMS. Secondly, the specific choice of muscles tested in the ASIA protocol could be a limitation to assessing walking ability. Indeed, a previous study found a strong correlation between walking ability and muscle strength.[14] However, walking ability correlated most strongly with the strength of hip extensors, flexors and abductors of the less-affected side. Of these, only the hip flexor is included in the ASIA protocol. In conclusion, testing motor outcome after iSCI should not be limited to the ASIA protocol alone, but extended with more responsive functional outcome measures.

The 6MWT and 10MWT did not differ between the sixth and 12th month after injury. Using the results from the 6MWT, the mean walking speed of the iSCI subjects was about $5.0\,\mathrm{km\,h^{-1}}$ (or $1.39\,\mathrm{m\,s^{-1}}$) 6 months after injury. Using the results from the 10MWT, the iSCI subjects walked at $4.5\,\mathrm{km\,h^{-1}}$ ($1.25\,\mathrm{m\,s^{-1}}$). Since normal walking speed can be defined at about $4.7\,\mathrm{km\,h^{-1}}$ ($1.31\,\mathrm{m\,s^{-1}}$),[15–17] it appeared that the iSCI subjects in the present sample had reached normal walking speed 6 months after injury. Therefore, an additional increase in walking speed after 6 months seems unlikely to occur.

Finally, the correlations between the 6MWT and 10MWT were excellent, throughout the time intervals at which they were assessed. This finding was comparable to the results of our previous study.[10] Indeed, both tests indirectly assess walking speed. In a future study, we will address the question of whether one of these tests could be redundant.

Methodological consideration

The sample of subjects assessed in the current study was relatively small. However, 75 iSCI subjects (18% of 407 complete and incomplete subjects) had a WISCI II score $\geqslant 1$ within the first month after iSCI. We selected those that had already completed their 1 year follow-up evaluation. Subjects that had not completed all tests at all four times were excluded. Therefore, we could analyze the data of only 22 subjects (29% of 75). These patients were selected as they are best candidates to show a significant recovery of walking capacity and therefore can serve as a good sample to evaluate the responsiveness of walking assessments. These iSCI subjects were good walkers, since they were able to stand or walk within the first month after their lesion. At 6 months after injury, one iSCI subject still needed crutches (WISCI II = 16), while the others achieved independent walking without the need for assistance or helping aids (WISCI II = 20). This might limit the generalization of the results to iSCI subjects with more impaired walking ability. However, Morganti *et al*[4] showed that after discharge most patients could be categorized into WISCI II items 13, 16 or 20. We expect that also within these other WISCI II categories (13 and 16) timed walking tests can differentiate the walking ability of patients with an iSCI.

Conclusions

The 6MWT and 10MWT showed better responsiveness compared to LEMS and WISCI II in iSCI patients with good walking capacity. Responsive assessment tools are needed to detect potential effects of existing or new therapeutical approaches on the functional outcome of iSCI subjects. The 10MWT and 6MWT appear to fulfill these criteria in iSCI subjects with walking ability: they are valid, reliable[10] and responsive tools to assess locomotor capacity.

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