Standardized assessment of walking capacity after spinal cord injury: the European network approach

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Standardized assessment of walking capacity after spinal cord injury: the European network approach

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Objectives: After a spinal cord injury (SCI), walking function is an important outcome measure for rehabilitation and new treatment interventions. The current status of four walking capacity tests that are applied to SCI subjects is presented: the revised walking index for spinal cord injury (WISCI II), the 6 minute walk test (6MinWT), 10 meter walk test (10MWT) and the timed up and go (TUG) test. Then, we investigated which categories of the WISCI II apply to SCI subjects who participated in the European Multicenter Study of Human Spinal Cord Injury (EM-SCI), and the relationship between the 10MWT and the TUG.

Methods: In the EM-SCI, the walking tests were applied 2 weeks and 1, 3, 6 and 12 months after SCI. We identified the WISCI II categories that applied to the EM-SCI subjects at each time point and quantified the relationship between the 10MWT and the TUG using Spearman’s correlation coefficients (r) and linear regression.

Results: Five WISCI II categories applied to 71% of the EM-SCI subjects with walking ability, while 11 items applied to 11% of the subjects. The 10MWT correlated excellently with the TUG at each time point (r > 0.80). However, this relationship changed over time. One year after SCI, the time needed to accomplish the TUG was 1.25 times greater than the 10MWT time.

Discussion: Some categories of the WISCI II appear to be redundant, while some discriminate to an insufficient degree. In addition, there appear to be ceiling effects, which limit its usefulness. The relationship between the 10MWT and TUG is high, but changes over time. We suggest that, at present, the 10MWT appears to be the best tool to assess walking capacity in SCI subjects. Additional valuable information is provided by assessing the needs for walking aids or personal assistance. To ensure comparability of study results, proposals for standardized instructions are presented. [Neurol Res 2008; 30: 61–73]

Keywords: Standardization; instructions; guidelines; timed walking test; WISCI II; SCI; gait; neurorehabilitation

INTRODUCTION

The need for sensitive assessment tools in the field of neurological rehabilitation is obvious. Current assessment tools have been designed largely to document functional outcome changes great enough to monitor clinically relevant improvements. These large changes are what have been considered as the most relevant for the patients and health insurance companies, and their assessment influences both (post-) clinical and rehabilitation decision making (e.g. can a patient already be discharged from rehabilitation? Is this patient independent enough to return to his or her home environment?). However, today, we are full of expectations that in the near future, new interventions will restore or repair damaged neural structures. Therefore, assessment tools should be able to detect smaller changes in function. On the one hand, more sensitive tools should be capable of detecting small improvements, thus demonstrating possible positive treatment effects. Although small, clinically-irrelevant treatment effects might be considered meaningless for the patient, they could demonstrate the ‘proof of principle’ of a new intervention. On the other hand, harmful interventions could be stopped as early as possible using more sensitive measures, before the patient’s condition becomes seriously affected. Thus, all of these considerations should be taken into account when assessment tools are evaluated on their usefulness for clinical works at present.

European Multicenter Study of Human Spinal Cord Injury

The European Multicenter Study of Human Spinal Cord Injury (EM-SCI; available at: http://www.emsci.org) was founded in 2003. Five (at present 19) spinal cord injury (SCI) rehabilitation centers across Europe standardized the assessment of their acutely injured...
patients. The aims of this initiative were: (1) to document the time course and extent of natural recovery after SCI achieved with current rehabilitative approaches; (2) to introduce and to validate assessment procedures; (3) to improve diagnosis and prediction of outcomes after SCI; (4) to prepare the clinical basis for new interventional studies. The multicenter approach of this project ensured the capture of a sufficient number of cases with a broad spectrum of neurological and functional deficits. Assessments were chosen to cover several domains of SCI, i.e. impairment and disability. Time points of assessments were set according to the natural recovery and practical aspects. SCI subjects were assessed within 2 weeks after SCI and after 1 (time window: 16–40 days), 3 (70–98 days), 6 (150–186 days) and 12 (300–400 days) months.

The neurological examinations encompassed the standardized assessment established by the American Spinal Injury Association. In addition, neurophysiologic recordings were performed on the long sensory and motor tracts (somatosensory evoked potentials and motor evoked potentials, respectively) and on the segmental level (electromyography and nerve conduction velocity). To assess the level of independence in SCI subjects, the revised spinal cord independence measure (SCIM II) was applied, while walking capacity was assessed using the revised version of the walking index for spinal cord injury (WISCI II; Figure 1), the 6 minute walk test (6MinWT), the 10 meter walk test (10MWT) and the timed up and go test (TUG).

There were several reasons for performing these particular walking capacity tests. The WISCI was already tested for validity and reliability for SCI subjects and was replaced in 2001 by the WISCI II (Figure 1). Indeed, valuable information can be obtained by scoring the walking aids and/or physical assistance needed by the patient. The three timed tests were chosen as each of them was expected to reflect different aspects of walking capacity. The 6MinWT was chosen because of its relationship with cardiovascular endurance, while the 10MWT was chosen as a measure to determine short duration speed that could be relevant for in-home activities. The TUG should relate with balance. All tests were performed at preferred speed, as this might reflect the level of performance of the SCI subject in the community.

**Validity, reliability and responsiveness of the WISCI II**

The WISCI was carefully and specifically designed by Ditunno and colleagues for SCI subjects (for a review see ASIA/ISCOS). Clinical experts described 19 items based on literature review and consultation with colleagues. These items were hierarchically ranked ordered by several international experts from the most impaired to the least. This was followed by several stages investigating concurrent and face validity, which resulted finally in a group consensus. This version was then subject to an international reliability study, in which videotapes of a representative group of patients was shown to several experts. Indeed, an excellent reliability was found. In the revised scale (WISCI II; Figure 1), two categories were added and this scale has been used in several international works. The WISCI II correlated well with several other scales indicating concurrent validity: the Barthel Index (BI) and the Rivermead Mobility Index (RMI; for both: Spearman’s correlation coefficient $r=0.67$), the spinal cord independence measure (SCIM; $r=0.97$) and the functional independence measure (FIM; $r=0.70$). It should be noted, however, that the SCIM, FIM and WISCI II were retrospectively scored, based on the description of walking in the SCI subjects charts. Furthermore, the WISCI II correlated with the Lower Extremity Motor Score ($r=0.58$). It also showed good correlations with the 6MinWT (Spearman’s correlation coefficient $r=0.60$), the 10MWT ($r=-0.68$) and the TUG ($r=-0.76$).

Sensitivity to detect changes over time (responsiveness) was also investigated. It was concluded that the WISCI II was more sensitive to walking recovery, as the WISCI II score distribution was wider at discharge (12/21 items) compared to other scores (BI, 3/16 items; RMI, 2/3 items; SCIM, 5/9 items; FIM, 4/7 items). However, in another study, the responsiveness of the WISCI II was lower compared to the 6MinWT and 10MWT in a select group of SCI subjects with good walking ability (WISCI II score $>1$ within the first month after SCI). While the timed tests could determine improvement in walking capacity between 1 and 3 months and 3 and 6 months after SCI, the WISCI II showed improvement only within the first 3 months. Similar results were observed in SCI subjects with poorer walking ability, who achieved a WISCI II score $>1$ within 3 months after SCI. In that study, the WISCI II showed significant improvement also between 3 and 6 months after SCI, although the median improvement was zero.

**Critical reflection of the WISCI II**

The authors of the WISCI wrote that the ranking of severity is based on the severity of the impairment and not on functional independence in the environment. However, as the WISCI is applied to test an activity (walking), it can be questioned whether ranking based on impairment can be justified. For example, motor impairment recovers differently compared to walking ability. The actual WISCI II ranking results in a somewhat confusing order of the items and a strong non-linearity. From a physical therapist’s point of view, independent walking should be scored better compared to walking that depends on the assistance of another person. Such aspects are not considered in the WISCI II, as for example, category 16 (ambulates with two crutches, no braces and no physical assistance, 10 m; Figure 1) is scored poorer than to 17 (ambulates with no devices, no braces and physical assistance of one person, 10 m). Furthermore, non-linearity can be observed if a SCI subject always needs braces. This patient could improve theoretically from 1 to 2, 3, 5, 6, 7, 9, 10, 12, 15, to a maximum score of 18. Such jumps in score are difficult to interpret.
Reliability of the WISCI has been reported to be excellent. However, the authors have investigated reliability by scoring photos or videos. This has the disadvantage that the initial process of determining what walking aids or physical assistance are needed by this patient is not included in the reliability testing. It can be considered relatively easy to observe and score what devices and/or assistance a chronic SCI patient uses to walk. However, at the acute stage, the decision as to what aids or assistance the SCI patient needs is determined by the therapist together with the patient. This decision making process has not been tested for reliability and might cause the most variability in determining the appropriate WISCI II category.

The responsiveness of the WISCI II, i.e., its ability to detect changes over time, appears to be poor compared to the timed walking tests. On the one hand, this could be explained by the ceiling effect of the WISCI II: SCI subjects that need no aids or assistance (WISCI II score 20) cannot further improve, although, for example, walking speed might increase. On the other hand, the categories of the WISCI II can cover a broad range of dependency. Physical assistance is described as 'any physical contact with the subject, including contact guard', which could cover a broad spectrum of physical support. Similarly, a wide variety in braces is available with different levels of support. Therefore, some patients might still need braces, but smaller ones, or need physical assistance, but considerably less and walk at a higher speed. All this is not reflected in changes in WISCI II category.

An assessment tool such as the WISCI II is subjected to cultural differences. Some differences between [Table]

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

Figure 1: Revised version of the walking index for spinal cord injury (WISCI II) reprinted by permission from Macmillan Publishers Ltd.
Europe and the USA are reflected in the preferences for walking aids. For example, while axilla crutches are predominantly used in the USA, in Europe, forearm or Canadian crutches are more common. Forearm crutches are considered as ‘partial bearing’ devices, because they do not support the full weight and are primarily used to give body stability (as opposed to leverage, like axilla crutches provide). Furthermore, initially, the WISCI II considered a walker to be rigid, without the use of wheels. However, walkers with wheels are regularly used in European centers. Now, the WISCI II also considers walkers with wheels, although this should be identified in the descriptors. Similarly, other devices used for bracing such as ace wraps or splints should be coded as brace and described under ‘other’. In German speaking countries, orthopedic shoes (Künzli SwissSchuh AG, Windisch, Switzerland) are widely used to reduce drop foot and increase lateral stability. We suggest that these shoes should also be considered as ‘braces’. However, should alpine boots that increase the passive stability around the ankle–foot joint be considered braces as well?

Furthermore, the WISCI II is subjected to new inventions in the field of walking devices. Therefore, the guidelines should be adapted from time to time (as stated by the authors). For example, we were recently confronted with a relatively new device that provides a seat and trunk support for the patient (Meywalk 2000, Meyland-Smith, Taars, Denmark; Figure 2). Should this be considered as a wheelchair that allows forward movements by the legs (in this case, WISCI II category 0 might apply)? Or is this a walker with wheels and additional bodyweight support that compensates for the loss of upper extremity supportive function in tetraplegic patients (WISCI II category 13), as these patients need more leg muscle strength for walking compared to paraplegic patients?

General validity, reliability and responsiveness of the 6MinWT

We assume that no test has been more thoroughly investigated than the 6MinWT. The 6MinWT was originally applied to patients with respiratory diseases and chronic heart failure. In the cardio-respiratory domain, the 6MinWT is the test of choice. Indeed, in patients with primary pulmonary hypertension, the distance walked during 6 minutes correlated strongly with peak oxygen levels. Also in patients with chronic obstructive airways and asthma, the 6MinWT correlated significantly with lung volume measurements. This might be the reason why the 6MinWT has been applied to many different subject groups, with the aim of assessing cardiovascular endurance.

The 6MinWT has been tested for reliability in different patients groups. The 6MinWT is considered reliable when tested in healthy children and elderly subjects, as well as in subjects with stroke, acquired brain injury, cerebral palsy, fibromyalgia, multiple sclerosis and cardiopulmonary disease. In patients with heart failure, the responsiveness of the 6MinWT is controversially discussed. In the RESOLVD study, the quality of life measures showed better responsiveness than the 6MinWT, while the responsiveness was considered good in elderly patients with heart failure. In patients with chronic obstructive pulmonary disease, the endurance shuttle walking test was found to be more responsive compared to the 6MinWT. Elderly subjects who underwent a functional training program showed less change in 6MinWT compared to a physical performance test. However, the 6MinWT showed good responsiveness in patients with fibromyalgia. The best initial estimates of small meaningful changes in elderly subjects were near 20 m and of substantial change near 50 m for 6MinWT. For clinical use, small changes in the distance walked during 6 minutes are detectable.

Validity, reliability and responsiveness of the 6MinWT in SCI patients

The 6MinWT has been applied to SCI patients in several works. Concerning construct validity, the strength of the hip flexors at the less affected side correlated well with the distance walked during 6 minutes. Bilaterally, hip flexor and abductor muscle strength correlated best with the 6MinWT and gait speed. A concurrent validity study showed that the 6MinWT correlated well with the WISCI II (r = 0.60), the 10MWT (r = -0.95) and the TUG (r = -0.88).

While inter-rater reliability can be considered good, intra-rater reliability showed an improved 6MinWT performance between the first and second trial. The responsiveness of the 6MinWT can be considered good in SCI subjects. Chronic SCI subjects who underwent a locomotor training program using a driven gait orthosis improved their distance walked during 6 minutes and gait speed, while the WISCI II showed no change. In addition, in a small group of SCI subjects,
both the 6MinWT and the 10MWT improved between 1 and 3 months and 3 and 6 months after SCI, while the WISCI II showed improvement only between 1 and 3 months.

Critical reflection of the 6MinWT

The standardization of the 6MinWT is more difficult compared to the 10MWT, as it depends strongly on the facilities. In some works, the subjects performed the 6MinWT by walking up and down a pathway of a specific length. This has the advantage that it could also be applied in settings with limited space. However, walking speed might be negatively influenced by the turns. Indeed, in stroke patients who had to walk up and down, the 10MWT speed overestimated the 6MinWT speed, while when they walked in a square, the speeds were comparable.

Therefore, this test should be performed with the least amount of turns possible. Furthermore, as encouragement had a substantial impact on the distance walked during 6 minutes in both cardiac and the respiratory patients, the test instructions should be rigorously standardized.

Although the reliability of the 6MinWT has been reported to be high, several works indicated that the 6MinWT performance improved significantly after the first trial in healthy subjects as well as in patients with cerebral palsy, fibromyalgia, SCI and cardiopulmonary problems. It is therefore recommended that the subjects perform at least one test trial before performing the actual measurement.

The 6MinWT appears to be redundant in some groups of patients with neurological disorders. Patients with stroke and SCI showed no difference between short duration walking speed and speed during 6MinWT. This was even the case when tested at maximum walking speed. It might indicate that in patients with neurological deficits, the distance walked during 6 minutes is not limited by cardiovascular impairments, but by other deficits, for example, sensorimotor deficits. Indeed, in patients with stroke, there was no relationship between the 6MinWT and cardiovascular endurance. Even in patients with severe lung diseases, the 6MinWT was rather related to muscle function than to cardiac or ventilatory impairment.

A selection bias could occur, as not all patients who are able to walk (WISCI II>1) perform the 6MinWT. Physical therapists tend not to test subjects who have poor walking ability, although these patients are allowed to take a rest during the 6MinWT. Especially at onset of the rehabilitation, this leads to a small number of patients who have performed the 6MinWT. Thus, especially in patients with poor walking ability, a discrepancy might exist between short and long duration walking speed, which has not been assessed so far.

General validity, reliability and responsiveness of the 10MWT

The 10MWT represents a quick and easy measure and can be applied to any population able to ambulate the required distance. Reference values for gait speed exist for different ages and gender, although these were not derived from 10 meter testing. The 10MWT was subject to concurrent or construct validation. It has been applied to both healthy subjects (e.g. elderly subjects) and different patient groups with neurological disorders such as Parkinson’s disease, stroke, multiple sclerosis. In patients with cerebral glioma, the 10MWT correlated well with the BI. In children with neuromuscular disease, the 10MWT correlated well with a 10 minute walk, although the self-selected speed was higher for the 10MWT. It has also been applied in patients with orthopedic disorders, e.g. with lower limb amputation. Patients with a transfemoral amputation walked faster compared to those with a transfemoral amputation.

The 10MWT showed good reliability in patients with mixed neurological diagnoses (ICC=0.93) stroke, multiple sclerosis and Parkinson’s disease.

The 10MWT also showed good responsiveness in acute stroke patients, although the 5 meter walk test appeared to be more responsive compared to the 10MWT.

Validity, reliability and responsiveness of the 10MWT in SCI patients

Concerning construct validity, the strength of the hip flexors at the less affected side correlated well with gait speed. Bilaterally, hip flexor and abductor muscle strength showed the highest correlations with gait speed. Concerning concurrent validity, the 10MWT correlated well with the 6MinWT (p=−0.95), TUG (r=0.89) and WISCI II (p=−0.68). Compared to the TUG and 6MinWT, it showed better inter- and intrarater reliability in SCI, as the subjects’ gait speed did not change between the first and second trial. The 10MWT was more responsive than the WISCI II in SCI subjects. It assessed changes during SCI rehabilitation between 3 and 6 months after SCI and in chronic SCI, it detected improvement in gait performance due to automated treadmill training, both unrevealed by the WISCI II.

Critical reflection of the 10MWT

Walking speed is considered as a surrogate for the overall quality of gait (and motor function). However, gait speed is difficult to interpret. What is a meaningful gait speed for daily life and which increment in speed can be considered relevant? Gait speed has not been correlated with disability scales in SCI. It is therefore difficult to determine its relevance for daily life. The speed needed to safely cross a street was found to be 0.6 m/s. This was used to separate SCI subjects into functional and non-functional walkers. In elderly subjects, among several variables, a walking speed above 1.0 m/s was associated with an independent lifestyle. Perera et al. found in elderly subjects that the best estimates of small, meaningful changes in gait speed were near 0.05 m/s, while substantial changes were near 0.10 m/s.
Similarly to the 6MinWT, the 10MWT has a floor effect for those subjects who are unable to walk 10 m. In addition, a ceiling effect might occur for those subjects who can walk a longer distance at the same speed. The latter effect is expected to be less for the 6MinWT.

In stroke, it has been shown that the 10MWT speed overestimated the long distance walking speed. This was also the case for children with neuromuscular disease. However, in a recent study, these findings could not be confirmed for SCI subjects. The 10MWT speed did not differ from the 6MinWT speed 1, 3 and 6 months after SCI. This is in line with a recent study in stroke.

**General validity, reliability and responsiveness of the TUG**

The get up and go test was modified by introducing a timed component (TUG). The test was validated in frail, elderly subjects and was shown to correlate moderately with gait speed, the Berg balance scale and the BI. Concurrent validity was good in patients with chronic stroke. In patients with multiple sclerosis, the TUG correlated well with other static and dynamic balance tests, although all tests showed poor discriminative ability between fallers and non-fallers. The discriminative ability of the TUG to predict falls was good in subjects with stroke, but contradicting findings exist in community-dwelling elderly people. The TUG could discriminate between geriatric subject groups who used different walking aids. In children, the TUG could differentiate well between children with cerebral palsy or spina bifida and healthy ones, as well as between children of different ages. Good concurrent validity was found in patients with lower limb amputation.

Reliability was excellent in young and elderly healthy subjects, as well as in subjects with Parkinson’s disease, chronic stroke and knee arthroplasties. Reliability was poorer in patients with total hip and knee arthroplasties and in elderly subjects, cognitive impaired or unimpaired. The responsiveness of the TUG was good in young children in that it detected change over a period of five months. It was also responsive in older subjects participating in geriatric rehabilitation. It also detected deterioration and improvement in the early post-operative period after total hip and knee arthroplasty. In patients with acute stroke, the responsiveness of the TUG was less compared to, for example, the 5 meter walk test.

**Validity, reliability and responsiveness of the TUG in SCI patients**

Concurrent validity is good as a strong correlation was found between the TUG and the WISCI II at the same rater. To our knowledge, no information exists about the responsiveness of the TUG in SCI subjects.

**Critical reflection of the TUG**

In patients with Parkinson’s disease or SCI, test performance increased between the first and second trial, which influences reliability. It is therefore recommended that similarly to the 6MinWT, the subjects should perform a test trial at least once before performing the measurement.

The TUG correlated excellently with the 10MWT, which might indicate redundancy.

A slight disadvantage of the TUG is that it cannot be converted into speed, as can be carried out with the 10MWT and 6MinWT. The speed of subjects unable to perform the 10MWT or 6MinWT can be set at 0 m/s. This is not possible for the TUG and makes statistical analyses more difficult.

An advantage of the TUG is that a more complex task is tested rather than ‘just’ walking, which might better reflect daily activities. However, as it combines several important tasks in one test, it scores the whole composite of standing up, walking, turning and sitting down, which might decrease the sensitivity of the information gained. It might be more accurate to test the different phases separately: the sit-to-stand-to-sit test could be performed to test standing up and sitting down. As this test should be performed with crossed hands, it might be more related to upper leg strength than the TUG, in which the subject can use the arms when standing up and sitting down. Walking could be tested by the 10MWT. Turning might be tested by timing and counting the number of steps needed to turn 360°, which has successfully been applied to elderly people and patients with Parkinson’s disease.

**Aims of this study**

This overview shows that the assessment of walking capacity has been extensively investigated in a variety of patient populations, but much less assessed in SCI patients. The aims of this study were to investigate: (1) which WISCI II categories apply to the EM-SCI subjects; (2) the relationship between the TUG and the 10MWT, as results from a previous study might suggest that these tests provide similar information.

**METHODS**

Retrospective analyses were performed of the EM-SCI database. At the time of analysis, the EM-SCI database contained data from 917 subjects. The numbers of missing observations were the largest 2 weeks (difficult to assess at this early time point in most European centers) and 12 months (unfinished follow-up) after SCI. To investigate which WISCI II categories applied to the SCI subjects, the frequency of each category was presented as a percentage for each time point. The percentages of each WISCI II category were averaged for all time points.
The walking tests were applied by trained physical therapists. The SCI subjects performed the 10MWT with a ‘flying start’, i.e. they walked ~14 m, while the intermediate 10 m were measured to compensate for acceleration and deceleration effects. The TUG was performed according to a previous study. However, the SCI subjects initiated the test themselves, instead of responding to a ‘go’ signal. The relationship between the 10MWT and the TUG was investigated using linear regression and correlation analyses. Again, separate analyses were performed for each time point.

RESULTS

Several WISCI II categories (Figure 1) applied rarely to the EM-SCI subjects (Table 1). Each of the categories 2, 7, 10, 14 and 18 applied on average to less than 1% of the SCI subjects with some walking ability (WISCI II > 0; final column in Table 1). In addition, the categories 3, 6, 11, 15, 17 and 19 applied to less than 2% of the SCI subjects with a WISCI II above 0. These 11 categories applied to 11% of walking EM-SCI subjects. In contrast, a large proportion (71%) of the SCI subjects with some walking ability could be categorized into the items 1, 8, 13, 16 and 20.

Table 1: Frequencies of WISCI II categories

<table>
<thead>
<tr>
<th>WISCI II</th>
<th>2 weeks</th>
<th>1 month</th>
<th>3 months</th>
<th>6 months</th>
<th>12 months</th>
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<tr>
<td>n</td>
<td>%</td>
<td>n</td>
<td>%</td>
<td>n</td>
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*The average percentage was calculated over all five time points for those SCI subjects with a WISCI II score > 0 (some ability to stand or walk). n, number; %, the percentage of SCI subjects that have a WISCI II score > 0.
DISCUSSION

The main findings of this study were the following: (1) many EM-SCI subjects were categorized in a limited number of WISCI II items, while half of the WISCI II categories applied to a small number of subjects; (2) in general, the TUG correlated excellently with the 10MWT, but the relationship changed over time. As the rehabilitation process continued, the number of SCI subjects with a low WISCI II score tended to decrease, while higher WISCI II scores applied more frequently to the EM-SCI subjects. The items 1, 8, 13, 16 and 20 applied frequently to SCI subjects with walking ability. These findings are in line with those from Morganti et al.\textsuperscript{12}, who found that most.
walking SCI subjects could be scored 13, 16 or 20 after rehabilitation.

In contrast, about half of the WISCI II categories applied to 11% of the EM-SCI subjects. Redundancy of the WISCI II has already been previously addressed\textsuperscript{12}, as the WISCI II correlated excellently with the SCIM II mobility category for short distances. The high correlation of 0.97 indicated that 94% of the variation of the WISCI II (which has 21 items) could be explained by the SCIM II (which has nine items)\textsuperscript{12}. The present results indicate that if a shorter version of the WISCI II would be desired, the categories 1, 4, 5, 8, 9, 12, 13, 16 and 20 (Figure 1) could describe the appropriate need of physical assistance and/or walking aids in 80.9% of the EM-SCI subjects with some walking ability.

**Relationship between TUG and 10MWT**

Although the TUG and the 10MWT correlated excellently with each other, the relationship was not fixed, but changed over time. The time needed to perform the TUG (compared to the 10MWT) decreases over time. Especially 1 month after SCI, the TUG might provide additional information, as only half of the variation in the 10MWT could explain the variation of the TUG. This difference might be related to an impaired balance, which is suggested to be related to the TUG\textsuperscript{10}. However, over time, the TUG might become redundant as at least 75% of the variation in the TUG is covered by the 10MWT results. In the chronic stage (1 year), the TUG can be estimated by multiplying the time needed for the 10MWT by 1.25 times.
Aspects of walking capacity

In SCI subjects, the assessment of walking capacity is relatively new and information is lacking. For example, maximum walking speed has rarely been tested in SCI subjects. The preferred walking speed of SCI subjects may only partially reflect the potential to participate in the community. Maximum walking speed, for example, which may be needed to catch a bus or cross a street, might be a better measure of daily life ambulatory capacity. Furthermore, walking capacity is tested in a simplified environment (i.e., a well-lit corridor, straight path, no disturbing factors, etc.), which might be less applicable to daily life. New tests might assess the capacity to adapt walking to external demands (walk over uneven floors, ascend or descend slopes, avoid obstacles) or evaluate the influence of attention on walking, by applying the dual task approach.

Furthermore, depending on the research question, different aspects of walking capacity might be relevant. For example, the application of functional electric stimulation to improve walking ability is still controversially discussed. However, FES systems are improving and might allow independent walking for subjects who are normally wheelchair bound. One goal could be to increase the maximal non-stop covered walking distance for SCI subjects (unrestricted for time). However, at present, we are unfamiliar with an appropriate standardized test protocol.

Standardization of walking tests

To ensure comparability of results (especially in multicenter trials), rigorously standardized assessment protocols are needed. We therefore propose instructions for the walking capacity tests discussed in this study and hope that these proposals might initiate a discussion concerning the standardized assessment of walking tests in the field of SCI and perhaps even in rehabilitation in general.

WISCI II

While at present different instructions are available for the use of timed walking tests, there are clear guidelines available for the WISCI II at: http://www.spinalcordcenter.org/research/wisci/resources/wisci-guide.pdf. The scoring form and descriptors are available at: http://www.spinalcordcenter.org/research/wisci/resources/wisci-scoring-form.pdf.

Timed walking tests

If more than one test is applied during a single session, we propose to perform the less fatiguing test first (e.g., preferred walking speed test before maximum speed test, or the 10MWT before the 6MinWT). Sufficiently long rest periods between each test should be taken and dress shoes should not be allowed. We suggest that the patient initiates the test and not that he/she should react on a ‘go’ signal, as we do not intend to measure reaction time. A stopwatch with an accuracy of 1/10 seconds is required. In addition to the timed tests, the WISCI II can be used to score the need for walking aids and assistance. For all tests, the investigator should be positioned next to the patient. In this way, the beginning and end point of the timed pathway can be better determined and assistance can be provided if required.

6MinWT

The environment for 6MinWT might be difficult to standardize. A flat, smooth, non-slippery surface, with no disturbing factors, is required and the pathway should contain as few turns as possible (preferably a large round or oval shaped path). Distances should be marked at least every 5 m. The total distance should be written down in meters.

Subjects are instructed to walk at their preferred (or maximum) walking speed (Figure 4a). The subject initiates the start of the test. After each minute, the subject should be informed about the time left and should be encouraged to continue his/her performance (Figure 4a).

Remarks

(1) If subjects are unable to walk for 6 minutes, rest breaks are allowed. After resting, the subject might continue with the test and the final distance is determined after 6 minutes. In such a case, a remark about the rest period should be written down; (2) it will be difficult to assess a 6 MinWT in subjects who are categorized to WISCI II scores of 2–5, as these subjects depend on parallel bars.

10MWT

The environment should be similar to that for the 6MinWT. The subjects are instructed to walk 14 m, while the intermediate 10 m should be marked on the floor. The measurement starts when the patient crosses a mark on the floor that indicates the onset of the 10 m pathway (‘flying start’). After 10 m (32.8 feet), the timer is stopped, but the patient continues until he or she has reached the end of the 14 m track. The time is written down to an accuracy of 1/10 seconds. Subjects are instructed to walk at their preferred (or maximum) walking speed (Figure 4b).

Remarks

(1) A special condition occurs when the patient requires the use of parallel bars, as these are rarely 14 m long. We suggest recording the middle 5 m between the parallel bars twice. The time of the first and second 5 m distances are summed and written down; (2) this test application is comparable to the 50 feet test that has sometimes been used in SCI patients, although time is only recorded for 10 m.

TUG

In general, we would suggest using most of the instructions of the modified TUG test as proposed by Podsiadlo and Richardson. However, we propose that...
the subject should initiate the test (Figure 4c). Comparable to the 10MWT, a similar environment of at least 4 m long is required. The chair should have a seat height of 46 cm and armrests (67 cm). The patient sits with his or her back against the chair, arms resting on the chair’s arm. As soon as the subject lifts up from the chair (buttocks), the time recording starts. The subject may use the armrests of the chair for support. After 3 m (9.8 feet), the subject turns and walks back to the chair. The timer is stopped as soon as the buttocks touch the chair again. The time is recorded and written down at 1/10 second accuracy.

CONCLUSION

There is a need for valid, reliable and responsive tests to assess walking capacity in SCI subjects. Clinically relevant changes in walking ability are important for the individual patient, while sub-clinical changes (on the population and individual level) become important when new treatments are evaluated for efficacy and safety. We presented four walking tests that are applied in the EM-SCI. We presented their positive and negative aspects, as well as new results showing that most SCI subjects could be categorized into a limited number of WISCI II items and that the TUG correlated well with the 10MWT, but that this relationship changed over time. We suggest that, at present, the 10MWT might be the best choice for assessing walking capacity in SCI subjects. Furthermore, we recommend the additional assessment of the dependence of the SCI subjects on walking aids or personal assistance.

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