Katholieke Universiteit Leuven
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Development of the Test of Wheeled Mobility for manual wheelchair users with a spinal cord injury

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Doctoral thesis in Physiotherapy & Rehabilitation Sciences

This thesis book is dedicated with love to my parents Uri and Aviva Fliess

"The aims of the rehabilitation team should not only focus upon the acquisition of skills to enable a person to get out of bed in the morning, but to assist him in finding a reason for doing so"

Treischmann 1988

Contents

Chapter 1

General introduction

Spinal Cord Injury

A spinal cord injury (SCI) is an interruption of the neural pathways in the spinal canal and is characterized by loss of sensation and motor dysfunction below the level of the injured lesion.

The cause of injury may be non-traumatic, i.e., due to a vascular hematoma, infection or melanoma; or traumatic, i.e. due to bruising of the cord in sport injuries, falls and motor vehicle accidents (which are the most common causes for SCI). The degree of motor and/or sensory loss is determined by the location and severity of the cord damage. In general, it can be stated that the higher the level of the lesion, the greater the loss of function[1].

There is a lot of heterogeneity within the population of SCI. It can be subdivided into two main groups: paraplegia and tetraplegia. According to the International Standards for Neurological and Functional Classification of Spinal Cord Injury[1] tetraplegia refers to impairment in the cervical segments of the spinal cord (between segment C1 and T1), resulting in impairment of function in the arms, the trunk, pelvic and legs. Paraplegia is defined as impairment in the thoracic, lumbar or sacral segments of the spinal cord (Below T1). In paraplegia, arm functioning is spared, but, depending on the level of injury, the trunk, pelvic and legs may be involved[1].

Another subdivision of SCI is into complete versus incomplete. An injury is defined as incomplete when partial preservation of sensory and/or motor functions is found below the neurological level and includes the lowest sacral segment. The term complete injury is used when there is an absence of sensory and motor function in the lowest sacral segment. Either paraplegia or tetraplegia may be complete or incomplete.

Completeness is classified using the American Spinal Injury Association Impairment Scale[2]. Grades A and B indicate that the lesion is motor-complete, meaning that there is no motor function preserved below the lesion level. Grades C and D indicate that the lesion is incomplete and that there is some motor function preserved below the lesion level. Grade E indicates that the motor function is normal[3].

Besides a loss of sensation and motor functioning, there are several secondary health problems and deficiencies associated with SCI. In most persons with SCI, urinary, bowel, and sexual function will be impaired because these functions are controlled at the lower levels of the spinal cord. Other typical secondary impairments are breathing problems, pressure sores, pain, autonomic deregulation, and spasms[4].

Only two studies presenting SCI occurrence worldwide were found in international literature[6, 7], reporting a wide prevalence range of 223–755 per million inhabitants[8], and annual incidence rate of SCI between 10.4 and 83 per million inhabitants per year. One-third of the individuals with SCI are reported to be with tetraplegia, and half of the SCI population has a complete injury. The mean age at which the SCI occurs is reported as 33 years old, and the gender ratio between males and females is 3.8/1 respectively[8].

Expected Functional Outcomes after Spinal Cord Injury

Functional outcomes after SCI vary from person to person, depending on many factors: the level and completeness of the injury, neurologic recovery, associated complications (e.g. contractures, spasticity), the amount of rehabilitation training, age, body size, weight, motivation, family support and financial status[9]. The “Clinical Practice Guidelines (Outcomes) For Health-Care Professionals”[10] and consumer guide “Expected Outcomes, What You Should Know”[11], contain tables with expected functional outcomes at several levels for complete SCI. The authors emphasize that the suggested outcomes must be adapted to each individual’s unique characteristics, capabilities and circumstances. The expected outcomes are expressed in terms of required assistance and equipment. They are not qualitative or quantitative and they are not based on well-selected aspects of wheelchair skill performances, and only few aspects of mobility are considered. Field-Fote et al. (2009)[5] presented a table with "the expected functional outcomes for motor complete SCI based on neurological level" and describes specific strategies for accomplishing these outcomes. In their table for example, individuals with a C8-L2 motor complete SCI should be able to perform wheelie skills (balancing on the rear wheels) including curbs up and down. However, there are no norms or standards available (e.g. maximal curb height or maximal slope percent) relating to each lesion level.

Assessment of Function

The advancement of science in the areas of medical and rehabilitative treatment for individuals with SCI, has led to a development of different methods which aim to restore function and regain quality of life to individuals with a SCI. The variety of clinical methods has led to an increasing need for an easily replicable standardized measurement tools, in order to facilitate outcome comparison by assessing intervention's effectiveness and efficiency[12,13]. Such assessment tools must include valid, reliable and sensitive measurements. "The ultimate goal for SCI assessment is to have internationally standardized methods for assessing the level of an individual's impairment and the individual's ability to perform various activities, then to transition these activities into participation in life situations"[5].

Wheeled Mobility

The concept of mobility is crucial in rehabilitation and can be described in cognitive, emotional, social and physical terms. Continuing to be mobile and having an optimal social and physical range of action are key objectives in SCI rehabilitation[14].

According to the International Classification of Functioning Disability and Health (ICF), the concept of wheeled mobility (WM) is a subcategory of the category "Moving around using equipment"[15]. Within the context of wheeled mobility for persons with a SCI, this definition is related to the ability to move as independently as possible, while using the wheelchair in different and quite challenging environments. Given that approximately 80% of the persons with SCI will remain dependent on a wheelchair for the rest of their lives[16], acquiring wheelchair skills has to be considered as an important part of SCI rehabilitation.

SCI rehabilitation, and particularly functional skill training in individuals with SCI, has much in common with coaching an athlete. Therapists should have critical observation and movement analysis skills, and be able to motivate and encourage their patient.

When training wheeled mobility, the goal is to teach general concepts (such as working with gravity, shifting the center of gravity, stability vs. instability, exploiting speed etc.) in addition to particular wheeled mobility skills.

Although wheelchair skill performance is seen as an important aspect for daily functioning, only limited research has been done to examine the development of wheelchair skill performance over time[17]. Neither the key biophysical nor psychological determinants of optimal wheeled mobility and skilled performance have been evaluated in much detail, within the context of rehabilitation.

As stated previously, ability to accurately measure wheeled mobility is necessary to make the appropriate choice of intervention and to evaluate patient's rehabilitation progress and treatment effects[18].
There are many wheeled mobility assessment tools, using different tasks and outcome measures. Therefore it is impossible to compare study results, or to systematically assess intervention's effectiveness and efficiency. There is no internationally accepted standardized measurement tool for assessing the level of wheeled mobility, neither consensus over which skills must be included in such a tool[19].

The Physical Activity for people with a Disability Model

The physical activity for people with a disability model (PAD) is the theoretical framework underlying the current study (Presented in Chapter 4, page 64). Van de Ploeg et al. integrated the ASE model (The Attitude, Social Influence and Self-Efficacy model[20] that is being used as a basis for interventions on behavioral change in the context of health and a physically active lifestyle), into a new model, to describe the relationship between Physical Activity behavior and functioning of people with a Disability – PAD[21].

Restoration of Mobility in Spinal Cord Injury Rehabilitation - The "Umbrella Project"

In 1998, a multicenter study named: "Restoration of mobility in SCI rehabilitation" supervised by Prof. Lucas van der Woude was started. This longitudinal 'umbrella project' is a multidisciplinary collaboration among five research groups, SCI units of eight rehabilitation centers in the Netherlands, and the Dutch-Flemish Society of Paraplegia[14]. It has generated datasets of a large group of people with SCI during and after clinical rehabilitation at 5 fixed points in time and allows the evaluation of wheelchair skill development over time and in association with different sets of personal and lesion-associated determinants. The current research project is a collaboration of KU Leuven and the Dutch "umbrella project".

Aim of this Thesis

This study aims to develop the Test of Wheeled mobility (TOWM) for hand rim wheelchair users with a SCI, in order to institute a standardized WM test, allowing the establishment of norms and standards for WM skills performance. This instrument should measure the level of well-selected WM skills, be methodologically strong and practically feasible.

The main research question is: which skills, scale and equipment should comprise a standardized test of WM that is valid, sensitive and reliable, aimed for fast and easy screening, differentiating between a wide range of performance levels among hand-rim wheelchair users with a SCI?

In addition to the TOWM development, this study aims to develop also a short “wheelie test” (wheelie refers to balancing on the rear wheels), based on the realization that "the ability to master a wheelie is perhaps the most important skill for the wheelchair user as wheelies permit access to areas and environments that would otherwise be inaccessible"[5]. Wheelie mastery requires understanding of the dynamic balance of the chair such that the individual is able to use the wheelie automatically and without excessive effort as necessitated by the circumstances or the environment. This study aims to develop the short and economical “Wheelie test” which might be applied as a substitute for the long version of the TOWM and be indicative for WM performance levels.

Thesis Outline

The set-up of the new Test of Wheeled Mobility (TOWM) was based on the primary definition chosen for wheeled mobility **(chapter 1)**;

In **Chapter 2**, a systematic critical literature review of available wheeled mobility skill tests is presented. This literature review enables to develop the TOWM relying on strengths of existing tools.

In **Chapter 3,** an assessment of changes in wheelchair skills performance levels of persons with a SCI at the time of discharge from inpatient rehabilitation (t1) and 1 year after discharge (t2) was conducted based on the Dutch prospective longitudinal study. This was based on existing data from the "Wheelchair Circuit" test developed by Kilkens et al.[17] and the Dutch "umbrella project" (www.scionn.nl). An attempt was also made to determine the personal and environmental factors that contribute the most to changes in wheelchair skill performances.

Chapter 4 and 5 describe the development, validity and reliability testing of the perceived "Self-Efficacy in Wheeled Mobility" (SEWM) scale; this scale was developed for two main purposes: 1) Forming an "expert group" for discussions, planning and piloting the TOWM. The selection of these experts was based on the perceived Self-Efficacy in Wheeled Mobility scale's scores among wheelchair users with a SCI throughout Belgium; and 2) to be used in correlation with the scores of the TOWM (for concurrent validity testing).

Chapter 6 presents the result of an international survey on wheelchair skill necessity that was conducted during the Beijing Paralympic games, among trained manual wheelchair users with a SCI. the aim of this study was to create a hierarchical list of the most essential wheeled mobility (WM) skills for everyday life of wheelchair users with a spinal cord injury (SCI), and to compare perceptions of WM gained during and after clinical rehabilitation. The outcome of the survey was a sorted list of wheeled mobility skills to be included in the TOWM.

Chapter 7 and 8 describe the development process of the TOWM and of the short Wheelie test. Following the extensive development of both wheeled mobility tests, the validity, reliability and feasibility of the TOWM and the short Wheelie test were assessed in a cross-sectional study measuring wheeled mobility levels of wheelchair users with a SCI.

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Chapter 2

A systematic review of wheelchair skills tests for manual wheelchair users with a spinal cord injury: Towards a standardized outcome measure

Fliess-Douer O, Vanlandewijck, YC, Lubel Manor G, van der Woude LH. (2010). A Systematic review of wheelchair skills tests for manual wheelchair users with a spinal cord injury: Towards a standardized outcome measure. *Clinical Rehabilitation*, 24: 867–886.

ABSTRACT

Objective: To review, analyse, evaluate and critically appraise available wheelchair skill tests in international literature and to determine the need for a standardized measurement tool of manual wheeled mobility in those with spinal cord injury (SCI).

Data sources: A systematic review of literature (databases PubMed, Web of Science and Cochrane Library (1970 – December 2009).

Subjects: Hand rim wheelchair users, mainly those with spinal cord injury.

Review methods: Studies' content and methodology were analysed qualitatively. Study quality was assessed using the scale of Gardner and Altman.

Results: Thirteen studies fell within the inclusion criteria and were critically reviewed. The 13 studies covered 11 tests, which involved 14 different skills. These 14 skills were categorized into: wheelchair maneuvering and basic daily living skills; obstacle-negotiating skills; wheelie tasks; and transfers. The Wheelchair Skills Test version 2.4 (WST-2.4) and Wheelchair Circuit tests scored best on the Gardner and Altman scale; the Obstacle Course Assessment of Wheelchair User Performances (OCAWUP) test was found to be the most relevant for daily needs in a wheelchair. The different tests used different measurement scales, varying from binary to ordinal and continuous. Comparison of outcomes between tests was not possible because of differences in skills assessed, measurement scales, environment and equipment selected for each test. A lack of information regarding protocols as well as differences in terminology was also detected.

Conclusion:

This systematic review revealed large inconsistencies among the current available wheelchair skill tests. This makes it difficult to compare study results and to create norms and standards for wheelchair skill performance.

Key words: Manual Wheelchair, Assessment, Measurement, Wheeled Mobility, Wheelchair skills test, Rehabilitation, Spinal cord injury

INTRODUCTION

Manual wheelchair mobility is important for a large number of people, particularly those with spinal cord injury. The majority of people with a spinal cord injury (approximately 80%) are dependent on a wheelchair for their mobility for the rest of their lives[1]. To function independently, manual wheelchair users must possess a variety of wheelchair skills to be able to deal with the physical barriers they will encounter in various environments in daily life[2]. Manual wheelchair skill performance of people with spinal cord injury is positively associated with activities and participation[3].

In this context, "wheelchair skill performance" is defined as: "The ability to move around and overcome obstacles encountered when carrying out daily activities or social roles in a self-propelled wheelchair"[4].

A 'wheelchair skills test' consists of various tasks to be performed by the candidate under standardized conditions. A validated and reliable wheelchair skills test is necessary as a guiding instrument in the rehabilitation process of people with spinal cord injury and those with lower limb impairments. Such a tool can assist in making the appropriate choice of skills to be trained in rehabilitation as well as in the evaluation of training interventions. Furthermore, a standardized and accepted wheelchair skills test could be used to develop standards of wheelchair skills performance for individuals with different levels of impairment.

A review by Kilkens et al.[5] mainly focused on a broad description and comparison of manual wheelchair skills tests reported in the literature between 1966 and 2001. The main conclusion of that study was that there is no standard test to measure wheelchair skills performance; most of the tests have only been used in one or two studies, "a fact that makes it impossible to compare study results"[5]. The current study updates and completes Kilkens' review, focusing on self-propelled wheelchair users with a spinal cord injury.

Another more recent review by Mortenson et al.[6] identified and evaluated wheelchair-specific outcome instruments, using the ICF definitions as a framework[7,8]. This review focused mainly on statistical properties of the tests, which ranged from questionnaires to actual performance tests, and it incorporated powered wheelchairs as well.

A broad framework for mobility performance assessment of wheelchair users was presented by Routhier et al.[4]. According to Routhier et al.[4], Mortenson's et al. review focused on mobility in the context of *assessment*. The current study, however, focuses mainly on wheeled mobility in daily activities and social roles. Therefore, the objectives, analysis, and outcomes of the two reviews are very much complementary.

The main objective of this review is to systematically review, document, analyse and critically appraise the performance-based wheelchair skills tests for manual wheelchair users, especially those with a spinal cord injury, currently available in the international literature. An added value of this study will be that it facilitates selection of the most suitable components from the existing wheelchair skills tests, in order to develop a standardized test.

METHODS

A systematic review of the international literature was performed. The search aimed for actual performance-based hand-rim wheelchair skills tests. The databases used for selection of peer-reviewed articles were PubMed, Web of Science and Cochrane Library (from 1970 to December 2009). The database search and study appraisal were conducted by the first and third authors together in a systematic way. Only studies reported in English were selected.

Search strategy

Peer-reviewed articles were selected using the keywords wheelchair(s) and measurement combined with assessment. A second search using the keywords wheelchair(s) and rehabilitation, combined with mobility was performed. To assure that all relevant literature was included, a final search was performed, using the keywords mobility and wheelchair, while alternately adding the words skill, task, measurement, test, ADL, functional, instrument, performance, spinal cord injury, validity, reliability, pathology, behavior, activity, disability, assessment and quality of life. Initial study selection was based on title and on abstract when the title was not sufficiently detailed. References given in relevant reviews and relevant publications were also checked and examined. The outcome of this search strategy is described in detail in Figure 1.

Selection of criteria

Since the focus of this review is on performance-based wheelchair skills tests, especially for hand-rim wheelchair users with spinal cord injury, the following selection criteria were used: A test was selected if: (a) it was an observational test (assessments in real or controlled environments); (b) it was constructed for persons using hand-rim wheelchairs and intended to assess wheelchair skills performances; (c) the study sample also involved people with spinal cord injury; (d) available statistical data regarding reliability and validity was presented. A test was excluded if: (a) it was constructed for persons using powered wheelchairs; (b) tests were performed in a virtual environment; (c) assessment was based on questionnaires or interviews (where subjective and retrospective characteristics might strongly influence the outcome[9]); (d) tests were focused on "body functions and structures" (measuring specific physiological and-or biomechanical variables which do not comply with the terms of "activity" or "participation" domains as defined in the ICF[7,8]).

Quality Assessment

The quality of the selected papers (quality assurance system, QAS) was evaluated independently by the first and third authors according to a checklist for statistical review of general papers adapted by van Velzen et al.[10] from Gardner and Altman.[11] In case of disagreement of an item score, consensus was achieved through discussion. For each selected wheelchair skills test, the following aspects were identified, described and analysed:

- The assessed wheelchair skills: how clear were their specification and the reason for their inclusion in the test;
- The scaling and outcome parameters used to assess the wheelchair skills performance;
- The feasibility and complexity of the test (duration, number of skills included, environment and wheelchair type, availability of test protocols);

The psychometric properties: the reliability as well as validity information (if presented) was reviewed. Intra-class correlation coefficients [ICCs] > 0.75 or κ-values > 0.75 are defined as very good reliability[12]. Sensitivity to change, ceiling and/or floor effects were also reviewed (if presented).

Finally, a critical evaluation of strengths and weaknesses of the wheelchair skills tests was conducted. Only studies with sufficient quality (QAS≥60%[10,11]) were included in this phase of our study. The critical evaluation was based on the authors' opinion regarding the most suitable skills, scale, environment and equipment that should be included in a standardized wheelchair skills test for person with spinal cord injury. Different aspects were defined and assessed. For each aspect, the first author and the third author had to agree if it is "strength" or "weakness". In case of disagreement, the other authors were consulted. A test was considered "stronger" when it met more of the following aspects: (a) It tests necessary daily wheelchair skills in real life settings, rather than "lab"-based settings (e.g. using own manual wheelchair rather than a standardized wheelchair); (b) It tests wheelchair skills performances of persons with spinal cord injury; (c) It assesses the differences in level of wheelchair skills performances and/or tests the outcome of an wheelchair skills intervention in a sensitive and precise manner; (d) It presents quantitative data which facilitate comparison with other tests results or previous trials; (e) It presents qualitative data analysis, generated by experts, enabling trainers to improve their teaching skills and can be also used to enhance test sensitivity; (f) It lasts a reasonable amount of time (preferably no longer than 60 minutes); (g) It presents a final test score.

RESULTS

In total, 1506 articles were screened on basis of the title (Figure 1). Checking for double references and abstract relevancy rejected 97% of the findings. A total of 43 articles were identified for further consideration. Forty studies involved different forms of wheelchair skills examination, but not necessarily actual performance-based wheelchair skills tests. Of those 40 studies, only 13 met the inclusion criteria.[13-25]. Most of the excluded studies were found to be ‘a list of tasks’, aiming to evaluate an intervention or to detect differences between groups, rather than actual performance-based wheelchair skills tests. Two tests, which were included in previous literature reviews, were also excluded: ‘Functional Evaluation in a Wheelchair’ (versions 1 and 2) instrument[26, 27] was excluded because it was designed as a questionnaire to be administered over time to consumers of seating-mobility technology and not as an actual wheelchair skills performance test. The "wheelchair obstacle course"[28] (WOC) was excluded because it was developed for people with a cerebral vascular accident only.

The remaining 13 studies represented 11 different wheelchair skills tests. In two cases, Kilkens et al.[17,20] and Routhier et al.[14,15], the two studies of each author were considered as one since they presented the same wheelchair skills test in both studies. Of these 11 tests, 9 were developed in the last ten years (1998 - 2007). Study designs included cohort studies (8), cross sectional studies (2) and a descriptive study (1). Out of these 11 studies, 5 scored QAS above 6.5 points[13,14,16,17,22], having sufficient methodological quality following Gardner et al.[11].

Wheelchair skills assessment

The 11 tests covered 14 different skills which could be categorized to wheelchair maneuvering and basic daily living skills; obstacles negotiating skills; wheelie, and making transfers (Table 1).

Wheelchair maneuvering and basic daily living skill. Level propulsion forward and backward is the most frequent task tested. In three tests, the participants had to cover the same distance when going forward and backward[13,16,19,23]. A variety of distances and methods were used but the reason for choosing the specific distance or method was not mentioned in any of the tests. Maneuvering was tested four times[14,17,19,22]; Chair turning was tested in three tests[16,19,22]; Parking[16,19] (parallel parking) and Sprint[17, 20] were tested once (in two different studies).

Obstacles negotiating skills. The variety of tasks under this category is the largest. Ramp was tested five times[13,17,18,23,24], but with different slopes and distances. Curb/Sidewalk - Ten different curbs were tested (heights range 2.5 – 17.8cm). Only four tests used two different curb heights[13,14,15,23], in order to differentiate functional abilities. Incline/Slope was tested eight times, using a variety of inclines, with no consistency. Only two tests measured two different slopes within the same test to compare abilities[13,17,20]; two slope tasks were tested on a treadmill[17,20]; only one test measured crossing a slope[16]. Doorstep was tested six times[14,15,16,17,18,19,20,21]; none of the tasks used the same height of door threshold. Irregular surface was tested six times[14,15,16,18,19,22]. Overall, the tasks under this category lack sufficient explanation.

Wheelie. Only three tests measured the wheelie skill[16,19,22] as a separate task. The wheelie tasks included stationary, forward and backward and turn while wheelie. None of the wheelie tasks was clearly explained.

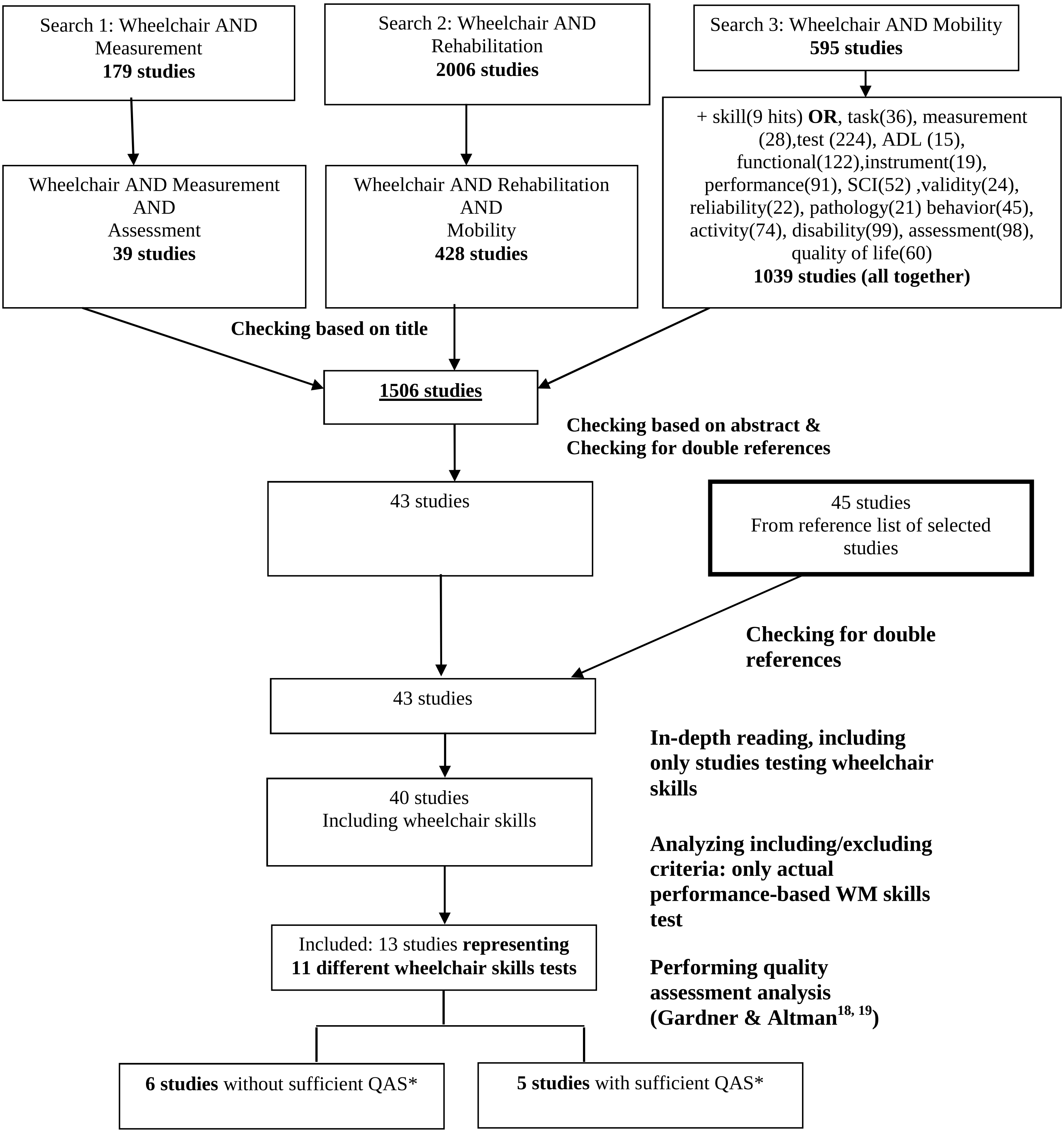
Making Transfer. This was a repeated skill in many tests and it was subcategorized into "vertical transfer" (up and down), "horizontal transfer" and "other transfers". Transferring from the floor to the wheelchair is more frequently tested than transferring to the floor (5/3). In horizontal transfer, only one test included a transfer into and out of a car[22].

Outcome and Scaling

Six out of 11 tests used a quality assessment scale[13,16,18,19,22,24] (i.e. level of independency scale, "pass/fail" scale, etc.), two used quantitative scales[21,25] and only three tests combined both quality and quantity parameters[14,17,23]. Four tests used a final test score expression, but each used a different type[15,16,18,19] (Table 2).

Feasibility

The feasibility variables are presented in detail in Table 2, only major aspects will be highlighted. Eight studies gave information regarding the duration of administrating the test. Most tests lasted between 30 minutes to 1 hour. The longest test duration was 1 – 1.5 hours[18], while the shortest was 15 minutes[23]. Total skills number for each test varied from a minimum of five[13] up to 61[22], and when focusing on wheeled mobility performance, the number of skills varied from a minimum of three[21] up to 30[16]. All tests were conducted in a rehabilitation center. Only 5 out of 11 tests supplied information regarding the wheelchair type that was used during the assessment[14,15,16,17,20,19,25]. In three tests participants used their own wheelchair[14,15,16,19], while in two tests standardized wheelchairs were used[17,20,25]. Description of quality of the wheelchair varied widely. Only three tests provided information regarding the period of time that the participants had been using the wheelchair previously to the first test trial[14,16,19]. Only 5 out of 11 tests described the test protocols sufficiently clearly, (i.e. enabling reproduction of test procedures)[13,15,20,21,23]. One test added photos to the article[15]. Some studies addressed that a copy of the entire test and score sheets are available upon request.



*QAS = Quality of selected papers

Figure 1**: Search strategy and the result of the search process**

Psychometric properties

The analysis and summary of the psychometric properties of the 11 tests is presented in Table 3.

Seven out of 11 tests presented information on validity[13-19, 22]. For most tests, content validity was based on the involvement of health professionals in the development of the test and on literature studies. Three tests[14,16,18] based the content validity also on wheelchair users' suggestions; two tests[15,17] based the content validity on related instruments. Construct validity was determined in seven tests[13-17,19,25,] correlating the new test with the Functional Independence Measure (FIM) instrument, and/or correlating the test result with age, gender, lesion, type of wheelchair or time using the wheelchair before the first test trial.

Only tests with sufficient reliability were included in this review. Test-retest reliability was assessed in five tests[14,16,19,21,25]. Time between the two trials varied from 1 day up to 28 days. Inter-rater was evaluated in eight tests [13-20, 23, 24] and Intra-rater was examined in four tests[16-20]. Only three studies reported sensitivity to change over time in wheelchair skills performances[13,17,22]. In these studies the tests were administered at the beginning and the end of the rehabilitation program. The above three studies, which assessed changes in wheelchair skills performances over time, were the only studies that indicated ceiling effect for the paraplegic group and higher responsiveness (detecting functional changes over time) in tetraplegic persons[13,17,20,22].

Strengths and weaknesses

The result of this evaluation is presented in Table 4, and will be incorporated in the discussion part of this article.

Table 1: **Skills review**

The category	Subcategory	# of test out of 11	The task
Wheelchair maneuvering and basic daily living skills	level propulsion forward and backward	9	**Direction**: *Forward* **1**± **3**ø **4**± **5**× **6**ø **7**± **9**± **10**× **11**± *Backward* **1**± **3**ø **6**ø **9**± **11**± **Distance:** *Forward* 20 feet – 50 m, *Backward* – the same distance as going forward except for one: **11** (10 feet) **Duration:** 180 sec – 6 min. **4,7** **Speed:** 0.56 – 1.11 m/s **4** **Method:** Level propulsion **1,3,6,9,10** Covering the greatest distance possible in 6 min **7**, wheelchair adjusted treadmill **4,** Street crossing **5**
	Chair turning	3	**Direction**: Turn in place left & right **3**± **8**× Turn moving left & right **3**ø Turn 3 points left & right **3**× **6**×
	Parking	2	**Task:** Parallel parking **3**× **6**×
	Maneuvering	4	**Task**: Figure 8 shape/slalom**: 4**± **6**×**,** Narrow corridor: **2**±, Wheelchair maneuvering indoors & outdoors: **8**×
	Sprint	1	**Task:** Propelling the wheelchair as fast as possible for 15m: **4**±
Obstacles negotiating skills	Ramp	5	**Slope:** 1:20 – 1:12 **1**± **4**± **5**× **9**ø **10**× **Direction:** up & down: **1 9** Up only: **4** Unspecified: **5 10** two different slopes in the same test: **1**
	Curb / Sidewalk	7	**Height:** 2.5 cm – 17.8 cm **1**± **2**± **3**± **5**× **6**± **8**× **9**ø **Direction:** Ascent & Descent: **3**± **6**± **8**× Ascent only: **1**± **2**± **9**ø unspecified: **5**× two different curbs in the same test:**1 2 3 9**
	Incline / Slope	6	**Height:** 1:16 - 1:8 **2**ø **5**ø **3**ø **6**ø 3% and 6% **4**± **Direction:** Going up and down: **2 3 6 8** Going up only **4** Cross slope: **3** **Time:** 10 sec **4**
	Doorstep	6	**Height: 2.5 cm - 7.5 cm 2**± **3**× **4**± **5**× **6**× **7**± **Task:** two different doorsteps in the same test: **2** request opening a door before passing: **5 7**
	Irregular surface	6	**Surface:** carpet: **2**× gravel: **2**× **3**× **6**× unspecified: **5 6 8** two different surfaces in the same test: **2 3**
Wheelie		3	**Task:** Wheelie- stationary: **3**× **6**× **8**× Wheelie forward: **3**× Wheelie backward: **3**× Wheelie Turn in place & while moving **3**ø
Making Transfer	Vertical transfer - up	4	**Task:** from the floor/mat to the chair: **1**± **8**± **9**± **10**± from bathtub to wheelchair **8**±
	Vertical transfer - down	3	**Task:** from wheelchair/chair to floor: **5**× **8**± 1**0**ø Transfer from wheelchair to bathtub: **8**±
	Horizontal transfer	6	**Task:** bad transfer/ treatment table/plinth: **4**± **5**× **9**± **11**± Toilet transfer: **5**× **8**± chair transfer (to another chair): **7**± **11**± , Car transfer: **8**ø
	Other Transfers	3	**Task:** Transfer out/in to a wheelchair: **3**× **6**× Transfer from wheelchair to shower / from shower to wheelchair **8**×

1= Middleton et al 2006, 2= Routhier et al 2004+2005, 3= Kirby et al 2004, 4= Kilkens et al 2004+2002, 5= Stanley et al 2003, 6= Kirby et al 2002, 7= Cress et al 2002, 8= Taricco et al 2000, 9= Harvey et al 1998, 10= Gans et al 1988, 11= Jebsen et al 1970
Clarity of explanation: Very clear ±, Quite clear ø, Unclear ×

Table 2: **Test analysis wheelchair skills tests – General summary:**

Main author + year	Name of the test (Ref #)	Objective	Study design	QAS	Study Population			Test design				Outcomes			Duration
					Health status	N M/F	Age	Way of choosing the skill	# WC skills / # skills	Test Environment	WC info	Parameters	Scale	Express final test score	
Middleton et al., 2006	FIM- 5 additional items 5-AML (21)	To better delineate important functional differences between groups with different levels of neurological impairment	Patients were tested within 72h of WM for the first time since injury, 1 month, 2 months, 3 months and 6 months later. COHORT	7	SCI: 11 Tetra, 28 para Asia A-C (D excluded)	39 32/7	R: 22-35 Mean: 28	previous test by Harvey, were modified to ensure suitability for tetra	4/5	SCI and rehabilitation 2 units in Sydney, Australia	No info	Quality	1-7: 7- complete independence, 6- modified independence, 5- supervision, 4- minimal assistance, 3- moderate assistance, 2- maximal assistance, 1- total assistance. Every skill has its own specific remarks for each point.	Shown only graphically	No info
Routhier et al., 2004+ 2005	Obstacle course assessment of wheelchair user performance-OCAWUP (22,23)	To evaluate WC user performance in potentially difficult environmental situation, for all propulsion methods and all clients group	17 experienced wheelchair users using 3 different propulsion methods were assessed twice on the 10 obstacle course. COHORT	7.5	SCI: 6; Neuromuscular disease: 4; CVA: 5; Amp: 2 after rehab min 1.5 years	17 10/7	R: 24-64 Mean: 50.9 ±12	consulting experts and scientific literature (based on Routhier 2004)	10/10	The Institute de Readaptation en Deficience Physique de Quebec (IRDPQ)	Their own WC that they have for at least 6 months. using 3 different propulsion methods	Time (sec.) + quality	DE- degree of ease: 3=total success; 2= success with difficulty; 1= partial failure; 0= complete failure.	GSE- global DEs scores are added to give a global score of ease from 0 to 30	No info
Kirby et al., 2004	WST 2.4 (24)	To evaluate the effect of WC skills training for WC users undergoing initial rehabilitation, to screen subjects before wheelie training, to compare the performance of manual WC and push-rim power assisted WC, to evaluate the effect of WC skills training for occupational therapists student at second year	Subjects were videotaped performing 50 skills twice. The order of skills was according to difficulty level and the natural groupings. If the first attempt failed a second try was allowed. Subjects were oriented to the test expectations. COHORT	10	AMP: 62; CVA+ TBI:52; musculoskeletal (MSK): 20; SCI :34; Able bodied volunteers (AB): 129.	298 140/158	R: 17-88 Mean: 8 ±22.5	The pilot study +17 WC users suggested the addition or modification of obstacles	30/50	Rehab. center	conventional : 119, Lightweight: 34 ultralight:15 Wheelchair was in the patients use for 2 days prior the test	Quality	0=fail, 1= pass, NA= Not Applicable, NG= Not a Goal.	Total WST scores: GAS = total goal attainment	27±9.3 min.

WM = wheeled mobility (wheelchair skills)
WC = wheelchair
Tetra = tetraplegic, para = paraplegic comp = complete, inco = incomplete
M = male F= female
R = range
SCI = spinal cord injury

Info = information
Ni = No information
Amp: amputation
QAS = quality of assessment score
Rehab = rehabilitation

Table 2 (continued)

Main author + year	Name of the test (Ref #)	Objective	Study design	QAS	Study Population: Health status	Study Population: N M/F	Study Population: Age	Test design: Way of choosing the skill	Test design: # WC skills / # skills	Test design: Test Environment	Test design: WC info	Outcomes: Parameters	Outcomes: Scale	Outcomes: Express final test score	Duration
Kilkens et al., 2002+ 2004	WC circuit (25, 28)	To asses mobility during and after clinical rehabilitation mainly for research purposes but also for clinical settings (longitudinal study)	Longitudinal Wheelchair Circuit was performed at start (t1) and at the end (t3) of inpatient functional rehabilitation COHORT	10	SCI: - para: 53 (18 inco) Tetra: 21 (9 inco)	74 51/23	R: 18-65	tasks were adapted from the mobility- related tasks use by Dallmeijer et al., Janssen et al., and Harvey et al.	8/9	8 Rehab centers in Holland	Hand-rim rigid frame Wheelchair was available in 2 seat widths	Quality, Time and HR	Ability Score: = yes/no, + 3 items could be scored as partially able 0.5), task performance time in sec. (2 skills), and % HR (2 slops task)	Scores are described in table. No general score that combines all three measurem ents	each task duration is described but not the overall duration
Stanley et al., 2003	WUFA (26)	To develop a performance-based functional measurement tool that is easy to administer and score, which can be applied to the wide range of individuals who use manual wheelchairs.	Subjects were videotaped one time while performing 13 skills. DESCRIPTI VE	3	Not described clearly. Including: CP, SCI, Spina bifida, CVA, ms, AMP and more	101 83/18	Male: 42.4±12 Female: 45.7±13	A panel of 6 PT experts in rehab. + survey of 30 manual wheelchair users	9/13	The Baltimore Veterans and Affairs center	No info	Quality	1 (total dependence) - 7 (completely independent). A score of 6-7 includes a specific time requirement for task completion.	Overall independe nce (similar to the FIM)	1.0-1.5 hours
Kirby et al., 2002	WST 1 (27)	Improvement for individual WC users, outcome measure for Rehab. programs, assist in testing research, developing new technologies	Subjects were videotaped while performing 33 skills twice. The protocol is similar to WST 2.4 COHORT	7.5	Amp:11 CVA: 4 musculoskel etal: 3 SCI: 3 Neuromuscul ar: 3	24 16/8	R: 18-85 Mean: 19±59	skills were based on previous literature review + occupational therapists opinion	13/33	Rehab. center	Their own WC; participants were using the WC min 2 days before the test; time using WC minimum 3 weeks. only 10 use the WC outside; method of propulsion (2 hands, one hand, one foot)	Quality	0-2: 0 = fail, 1=partial completion, 2 = successful	Overall % of success	29 min

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Table 2 (continued)

Main author + year	Name of the test (Ref #)	Objective	Study design	QAS	Study Population			Test design				Outcomes			Duration
					Health status	N M/F	Age	Way of choosing the skill	# WC skills / # skills	Test Environment	WC info	Parameters	Scale	Express final test score	
Cress et al., 2002	WC physical Functional performance - WC-PFP test (29)	To measure the ability of people using manual wheelchair to perform tasks which are important for living independently	Tasks were performed serially and participants were asked to work at maximal exertion yet to pace themselves to complete as many tasks as possible. COHORT	3	MS: 4; CVA: 2; polio:1, Arthritis: 1, TBI: 2, SCI:8	18 13/5	R: 18-67	Adaptation of the Continuous Scale Physical Functional Performance measure (CS–PFP)	3/11	a rehabilitation facility	No info	Quantity scores (weight, distance and time) in 4 domains: Upper body strength, flexibility, Endurance, balance and coordination.	Scores were transformed to a scale from 0 to 100 (=highest performance in the test population)	Reported Mean + SD in a table, only general score	40 min.
Taricco et al., 2000	Measurement scale VFM (30)	To evaluate the impact of rehabilitative interventions on the functional status of SCI patients	Scoring is done according to direct observation of patient performance, excluding 1 task that is simulated and 2 that are collected by interview (none of those are related to mobility). VFM was administered at the beginning and the end of the rehabilitation program. COHORT	9.5	SCI: Para: 67 Tetra: 33 81 had a traumatic etiology	100 77/23	R: 14-76	Input from the literature and specialists. (more details were reported in previous articles)	23/61	8 Italian SCI units	No info	Quality	1-5 scale: from inability to complete the task to completing the task without difficulties	Mean score for each domain at baseline and follow up	30-50 min
Harvey et al., 1998	Assessing mobility in paraplegic (31)	To quantify the mobility of wheelchair dependent paraplegics.	Each subjects performed the test twice at the same day, assessed by 2 different assessors. COHORT	4	SCI :Para 20	No info	Mean: 45.6± 16.8	Skills typically learned in physiotherapy programs	5/6	No info (most likely rehabilitation center)	No info	Quality (based on also on time to complete the task)	1 to 6 scale: Level of independence, time and task complexity, according to each task	Median and inter quartile range levels of mobility attained on each task	15 min.

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Table 2 (continued)

Main author + year	Name of the test (Ref #)	Objective	Study design	QAS	Study Population: Health status	N: M/F	Age	Test design: Way of choosing the skill	# WC skills / # skills	Test Environment	WC info	Outcomes: Parameters	Scale	Express final test score	Duration
Gans et al., 1988	TAMP - Tufts assessment of motor performance (32)	Providing comprehensive clinical evaluation of physical function and motor performance. To examine motor performance in sufficient detail to assist with treatment planning and to adequately describe and identify meaningful clinical changes in motor abilities.	Test was administered by PT/OT. Instructions and demonstration were given prior to each item. Breaks were provided as needed. Order of tasks: from fine to dressing, transfer and mat mobility and finally mobility. Tests were videotaped and analyzed at a later date. CROSS SECTIONAL	4.5	Orthopedic Surgery- 6, Closed head injury- 6, Muscle disease/atrophy - 3, SCI-5, CP-6, Other miscellaneous-14	40 14/26 (20 adults, 20 children)	Mean: 25.6±19.5	No info.	4/32	rehabilitation center	No info.	Quality	4 different scales in 4 dimensions: **Assistance- 5 scale points**, from independence to total dependence. **Approach- 2 scale points:** General technique used to complete the task. **Pattern- 2 scale points:** clinically important movement patterns in selected fine motor activities and in gate. **Proficiency- 3 scale points:** movement control, accuracy of extremity placement and aspects of coordination	Mean Kappa	less than 1 hour
Jebsen et al., 1970	Time measurement in a standardized test (33)	To measure various aspects of patient mobility by measuring the time necessary for independent completion of each of the group subsets.	Subjects were timed while performing each task. They were advised to perform each task as quickly as possible. Healthy subjects: short practice session was allowed before testing started. Subjects with disabilities: were tested on 2 occasions, 1 to 4 days apart. COHORT	3.5	100 healthy 18 patients 10 hemi paresis Low limb Amp: 4 peripheral neuropathy- 1 hip fracture- 1 polio- 1 SCI-1	100 50/50 Healthy	Healthy: 20 from each age group Patient: Mean: 49.7	No info.	6/31	No info.	16 and 18 inch seat width, large wheels in rear (standard wc)	Time (sec.)		Mean time of each subtest, No general score	30 min. for healthy 60 min. for patients

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Rehab = rehabilitation

Table 3: **Psychometric properties of the wheelchair skills tests**

Main author + year	Name of the test	Validity		Reliability			Sensitivity to change over time
		Content/Face	Construct/Concurrent	Test-retest	Intrarater	Interrater	
Middleton et al., 2006	FIM- 5 additional items 5-AML	1	± **A**	No info	No info	κ range .82-.96	although written "high responsiveness to change over time" it is refers to the tetraplegic group, while a ceiling effect is mentioned in the paraplegic group
Routhier et al., 2004+2005	Obstacle course assessment of wheelchair user performance-OCAWUP	1,2,3	§ **A** **B** (FIM) *r*=0.84, p≤0.05.	ICC range .74-.99 (time) κ range 0.09-1.00 (GSE – global score of ease) ICC ≥.96 (overall score)	No info	ICC ≥.98 (time) κ range .82-.96 (GSE – global score of ease) ICC ≥.97(overall score)	No info
Kirby et al., 2004	WST 2.4	2	**+ A** *r*=-0.434, p<0.001. º**A** r. *p*=0.38. ^ A *p*=0.0112. ∗**A B** (the global assessments of WC users' therapists and admission and discharge FIM scores) 0.394, 0.38, 0.31	ICC = .90	ICC = .96	ICC = .97	No info
Kilkens et al., 2002+2004	WC circuit	3	*Ability score* (t1 – t3): ± **A**. +**A** (only at t3) **B** (***FIM mobility score, peak power output and vo2 peak*-)** *Performance time score* ± A (only at t3) +B (FIM mobility score, peak power output, and peak oxygen uptake) *Physical strain score* ±A (only at t3) **B** (Peak power output and peak oxygen uptake- Inversely related)	No info	ICC =.98	ICC=.97	All 3 scores showed strong significant improvement between t1 and t3. The standardized responses mean (SRM) was 0.6 for ability score, 0.9 for performance time, and 0.8 for physical strain score.
Stanley et al., 2003	WUFA	1,2	No info	No info	ICC=.78	ICC=.96	No info
Kirby et al., 2002	WST 1	1	+A negative r p<0.05, ^**A** *p*=0.0085. **B** p = 0.008 (the occupational therapist global rating)	*r*=.65	*r*=.96	*r*=.95	No info
Cress et al., 2002	WC physical Functional performance - WC-PFP test	3	**B** (SIP – Sickness Impact Profile scale) significant correlation (*r*= -0.45) only for bathing and dressing (self-related health and upper body domain)	ICC .96	No info	No info	No info
Taricco et al., 2000	Measurement scale VFM	3	±**A** ∗**A** B (Barthel index, QIF, FIM)) ranged .67-.88	No info	No info	Was evaluated in previous phase of this project (published in Italian)	Scores had significantly improvement for tetraplegia and high level paraplegia between t1 – t3
Harvey et al., 1998	Assessing mobility in paraplegic	1	No info	No info	No info	κ range.82-.98	No info
Gans et al., 1988	TAMP - Tufts assessment of motor performance	No info	No info	No info	No info	κ range .65-.83	No info
Jebsen et al., 1970	Time measurement in a standardized test	No info	∗**A** (healthy people Vs. WC users)	r.85-.99 (time)	No info	No info	No info

Validity legend:
Content/Face:
1 – Involvement of health professional in development
2 – Involvement of WC users in development
3 – Based on related instrument
Construct:
A– Significant factor
Concurrent:
B –correlation with a related instrument / physiological parameters
t1 – first test trial **t3** – last test trial (mostly at the end of the rehab program)

Variables signs:
± Lesion level (tetraplegia/paraplegia)
"Motor completeness (complete/incomplete)
∗Diagnostic category (SVA, CP, AMP, SCI etc)
+Age
ºGender
^ Experience of WC use
§Propulsion methods

Table 4: **The critical evaluation (only tests with QAS above 6.5)**

Main author + year	Name of the test	Protocol + Design	Summary of strengths	Summary of weaknesses
Middleton et al., 2006	5 AML	Patients were tested within 72h of mobilizing in a wheelchair for the first time since injury, 1 month, 2 months, 3 months and 6 months later. COHORT	(b) Only SCI, Male & Female in a reasonable ratio (e) quality assessment of 7 levels for each skill * Popularity of the FIM	(a) Only 4 WM skills, suitable for rehabilitation use; No info regarding the wheelchair (c) No info about differences in ASIA; suitability of all tasks to tetraplegia ; ceiling effect on Paraplegic in general; (d) No info regarding the quantity data (e) quality scale based on level of independency (f) No info about feasibility (g) No expression of general score
Routhier et al., 2004+2005	OCAWUP	17 experienced wheelchair users using 3 different propulsion methods were assessed twice on the 10 obstacle of the OCAWUP. COHORT	(a)10 WM skills, suitable for daily use; Using their own wheelchair (d) time scale And (e) quality assessment of 4 levels, (g) GSE- global scores are added to give a global score of ease from 0 to 30	(a) Including motorized wheelchair; Skills are not including transfers and wheelie backwards (b) Not only for SCI (f) No info about feasibility
Kirby et al., 2002+2004	WST 1 and 2.4	Subjects were videotaped while performing 50 skills twice. The order of skills was according to difficulty level (from easy) and according to the natural groupings. If the first attempt failed a second try was allowed. Subjects were oriented to the test expectations. COHORT	(a)Using their own wheelchair, many WM skills (i.e.: left and right for the same skills) (f) it takes about 30 min. to complete the test (g) Total WST scores - allow comparison with previous trial	(a) Skills were not described in details; it is hard to base a future test on the articles. (b) not only for SCI (c) no info regarding sensitivity for change, no report regarding different level of WM in the group of SCI (d) No quantity data (e) Quality scale not sensitive enough (only pass/fail and NA and not a goal
Kilkens et al., 2002+2004	WC circuit	Longitudinal. Wheelchair Circuit was performed at start (t1) and at the end (t3) of inpatient functional rehabilitation. COHORT	(b) SCI only (big sample, (c) longitudinal, assessing changes over time	(a) Only 8 WM skills, 3 skills require treadmill, using transfer to treatment table = not suitable for everyday needs, rather lab examination (d) quantity data based only on the sum of two skills; HR of 2 skills only (e) quality scale only of 3 level (pass/fail/partially of 3 skills only (f) each task feasibility is described but not all test feasibility (g) No expression of a total score
Taricco et al., 2000	VFM	A direct observation of patient performance, excluding 1 task that is simulated and 2 that are collected by interview (none of those are related to mobility). VFM was administered at the beginning and the end of the rehabilitation program. COHORT	(a)test can be used in different settings (home, outpatient) (b) Only SCI, Male & Female in a reasonable ratio, paraplegic and quadriplegic, big sample (e) 1-5 quality scale	(a) 23 WM skills out of 61, not measuring only wheelchair skill performances (d) No quantity data (e) quality scale based on level of independency (f) between 30-50 minutes (not clearly described) (g) No expression of a total score

a. Test everyday wheeled mobility skills rather than "lab" examinations: using skills that are needed in everyday life, using their own manual wheelchair
b. WM test for person with SCI
c. Assessing the differences in level of wheelchair skills performances of SCI (optimal WM, good WM, moderate WM and poor WM) and testing the outcome of an WM intervention (or learning phase during the rehabilitation process) , sensitively and precisely
d. Quantity data for comparison with other tests or previous trails
e. Quality analysis (on field and/or video recorded performance, analyzed by experts) enable trainers to improve their teaching skills and also for the enhancement of the sensitivity of the test
f. Feasibility – duration of the test: no longer than 30 minutes
g. Express final test score

DISCUSSION

Today, individuals with spinal cord injury spend less time in the hospital during the acute phase of their injury, and the rehabilitation process is now more likely to be in the community, in day hospital or home environment[29]. It is therefore recommended that skills associated with the daily needs of this population will be included in wheelchair skills tests. Some of the reviewed skills do not comply with this recommendation. For example, in the level propulsion skill, the participant has to cover the same distance when going forward and backward, as if it has the same necessity in daily life. In the Wheelchair Circuit[17,20], three skills out of eight require the use of a treadmill. In contrast, the 10 wheelchair skills of the Obstacle Course Assessment of Wheelchair User Performances (OCAWUP)[14,15] are most relevant for daily needs of wheelchair users. In addition, this test is the only one that associates skill selection with the average height of pavements in Quebec City as well as correlating the level of inclines to the National Building Code of Canada. It is recommended that the skills to be included in a test are chosen according to a large survey among experienced wheelchair users, sorting out the most essential skills for daily life in a wheelchair. It is also advised that slopes, heights and other measurements selected for the test are associated with norms, standards and architectural accessibility codes, regional as well as universal.

Scaling and outcome parameters

Scaling method is a crucial aspect and has a direct impact on the responsiveness of the test. Some of the reviewed tests use only qualitative scales. Specifically, the 'pass/fail' ranking, used in the Wheelchair Circuit,[17,20], Valutazione Funzionale Mielolesi (VFM)[22] and Wheelchair Skills Test version 2.4 (WST 2.4)[16] tests, cannot guarantee a clear and sensitive distinction between levels of performance in groups but especially in individuals. Some tests evaluate performance ability by assessing only the 'degree of independency'. This may not reflect the actual performance level, since a person may be able to perform a certain wheelchair skill independently, but if it requires an unreasonable amount of time or high energy cost, the person might choose not to perform this skill in daily life. The most sensitive quality scales were found to be the independency scale of the Five Additional Mobility and Locomotor (5-AML)[13] test and the performance's quality scale of the OCAWUP test[14,15]. Some of the reviewed tests use quantitative scales (e.g. time score, heart rate, etc.). Such scales allow simple and objective comparison with other trials and tests. For instance, in the Wheelchair Circuit test[17,20] the highest statistical significant score was the 'performance time score', providing evidence for improvement in wheelchair skills performances over time. Nevertheless, Routhier et al.[14] mentioned that one should be careful with the use of time in short tasks (e.g. 'gets over 2 cm threshold'). If a wheelchair user takes 15 seconds instead of 10 (an extra 50%) to achieve a task, it does not necessarily mean that the wheelchair user has difficulties. To conclude, in a future standardized test it is suggested to combine both quantity measures and sensitive quality scales.

Feasibility and complexity

In general, the duration of a test is dictated by the number and complexity of the skills included, but in some of the reviewed tests there is a contradiction to this concept. On the one hand, some tests evaluate many skills in a relatively short time (the VFM[22] test assessed 61 skills within 30–50 minutes and the WST-2.4[16] assessed 50 skills within 27 minutes). An explanation to this observation is that some tests do not assess all the skills they contain, giving the observer the freedom to choose which skill to evaluate from the proposed list of skills. This involves a subjective judgment of the observer, eliminating skills that are 'not a goal' for the specific participant, and that therefore might reduce test sensitivity. It also makes a comparison between different testing difficult, if not impossible. On the other hand, some tests contain fewer skills but last longer (the Wheelchair Users Functional Assessment[18] test assessed 13 skills in 1–1.5 hours). Reducing the number of selected skill shortens test duration but may subject the test to ceiling effect (e.g. 5-AML[21] test which has a ceiling effect on paraplegics). The number of skills included in the test is a compromise between the need to cover many aspects of wheelchair skill performances and minimizing overlaps between the selected skills. More complex skills inherently include 'subskills'; when performing slalom the participant has to drive forward, and in this case the need to test level propulsion forward is questionable.

The chosen environment for all the tests reviewed in the present study was a rehabilitation centre, where it is easy to recruit participants, equipment as well as examiners, but whether an accessible rehabilitation centre is the most suitable environment for evaluating wheelchair skills that are required for daily life is debatable. Furthermore, patients in rehabilitation are rather immature in their wheelchair skills performances. Nevertheless, a distinction should be made between the location in which the reviewed studies took place for their validation and the ability to administer them outside rehabilitation centers for clinical purposes.

The type of wheelchair has an important impact on carrying out a task, especially when testing level of performance (e.g. type and wheelchair quality, tyre pressure, maintenance status, etc.) Using one's own wheelchair during the test would probably better reflect performance level but threatens the stability of the test. Aiming the wheelchair skills test for daily activities and social roles, the use of the participants' own wheelchairs is preferred, accompanied by a full description of the wheelchair used.

Accessibility to the test protocols is important in order to understand the instructions and settings of the tasks. Some of the reviewed studies lack a full description of the tasks, which may explain the multiplicity of tests. It is advised that each skill should be well described in the article. It is also recommended that the reader is given easy access to the full test protocols (e.g. through a website[16]). This will invite rehabilitation professionals and other researchers to use the same test, and may promote the development of a universal wheelchair skills test.

Psychometric properties

When conducting research in a rehabilitation domain, setting the goals according to precise definition of terms is critical as a guideline for developing the tool and choosing the most appropriate skills. A clear definition of terms, specifically of the outcome expressions (e.g. wheelchair user's 'function' or 'wheeled mobility'), is the foundation for ensuring a good content validity. Many of the reviewed tests lack a clear terms' definition; for instance, the Wheelchair Users Functional Assessment study (WUFA)[18] aimed to 'develop a performance-based functional measurement tool that needed to incorporate home and community wheelchair skills'. One of the skills included in the Wheelchair Users Functional Assessment is upper and lower dressing, but because of the absence of definition of terms, it is unclear why dressing is included as a wheelchair skill. In contrast, a good example where the objective of the test as well as definition of terms are presented can be found at OCAWUP[15]: 'the purpose of the OCAWUP is to assess and document the mobility performance of manual and motorized wheelchair users in potentially difficult environmental situations. Environmental situations are obstacles when they limit the social participation of an individual'[15]. Another example of unclear term definition is a confusion between 'ability' (e.g. sprint task) and 'motor skill' (e.g. 'transferring from the floor back into the wheelchair'), which is found in many tests. It is important to understand the differences between these two terms and to select tasks that clearly meet the definition of motor skill.

In a population of people with spinal cord injury, an individual might function at minimal (C3) or maximal (L3) levels. Ceiling and floor effects are the result of lack of precision and the ability of an instrument to detect meaningful changes in level of performance at the upper or lower ends of the scale. If individuals have reached the maximum rating in their first trial, more subtle improvement will not be reflected. The idea is to establish one test for all wheelchair users, similar to the Functional Independence Measure[30] that has been widely adopted by the rehabilitation community as a tool for use with diverse patient populations. Tools that generalize wheelchair user populations, however, may fail to differentiate between levels of performance. In the WST-2.4[16], although ceiling effect was not reported, the use of quality scale only could probably lead to ceiling effects (e.g. assessing '50 meter level propulsion forward' with a pass/fail scale will definitely produce a ceiling effect for all paraplegic clients). The VFM[22] was the only test that addressed the need to subdivide the spinal cord injury group. Despite this comment, the same skills were used to evaluate paraplegic and tetraplegic clients. Spinal cord-injured wheelchair users may demonstrate the best wheelchair skill performance, and could be the benchmark to reach in term of wheelchair skills. It is advisable to first develop sensitive wheelchair skills test specifically for the spinal cord injury population, with adaptations for the two subgroups (tetraplegic and paraplegic). Such a test might reduce ceiling or floor effects, and could be generalized later on to the entire wheelchair user population.

Most of the reviewed articles aim to assess the reliability and validity of the test, but do not derive norms and standards for wheelchair skill performances. Previous studies do not present data that can be compared with results from other studies. As revealed from the current review, there is no broadly accepted wheelchair skills test. Such an 'ideal' instrument should measure the level of selected aspects of wheelchair skill performance, be methodologically strong and practically feasible. Once a standardized wheelchair skill test has been developed, accepted worldwide and frequently used, it will enable norms and standards to be created for wheelchair skill performance.

Study Limitations and Strengths

This review was limited to actual performance-based wheelchair skills tests published in peer-reviewed articles that were available in English only. Since this review aimed to serve as a base for developing a standardized manual wheelchair skills test for those with spinal cord injury, assessment tools that were constructed exclusively for other disabilities were not included, although some lessons may be also drawn from those instruments and studies.

The detailed skill-specific review along with general analysis is a particular strength of the study, since it points out the important aspects of each test and facilitates a selection of the most suitable components, enabling the development of a standardized wheelchair skills test, relying on the strengths of existing measurement tools.

Conclusion

As shown in this review, many wheelchair skills tests are applied to the measurement of wheelchair skill performance using a large variety of skills, equipment and outcome measures. The main conclusion is that there is no one broadly accepted wheelchair skills test allowing comparison of study results. It is hoped that this review will appraise the need for agreement among researchers as to which skills must be included as well as standardization of the use of one measurement instrument. Cooperation between professionals in the development of this 'ideal' test, as well as the promotion and endorsement of such a tool, is desirable in order to develop universal norms and standards for wheelchair skill performances.

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Chapter 3

Wheelchair skills performance between discharge and one year after inpatient rehabilitation in hand-rim wheelchair users with a spinal cord injury

Fliess-Douer O, Vanlandewijck, YC, de Groot S, Marcel W Post, van der Woude LH (2012). Wheelchair skills performance between discharge and one year after inpatient rehabilitation in hand-rim wheelchair users with a spinal cord injury. *Journal of Rehabilitation Medicine,* Accepted for publication.

ABSTRACT

Objectives: To study possible changes in wheelchair skills in participants with spinal cord injury (SCI) between discharge and one year after rehabilitation, and to determine whether changes in wheelchair skill performance are related to lesion and personal characteristics, self-efficacy, and wheelchair satisfaction.

Study design: Prospective cohort study.

Setting: Eight rehabilitation centers with SCI unit in the Netherlands.

Methods: 111 Participants performed the Wheelchair Circuit twice: at discharge (t1) and one year after (t2). Personal/lesion characteristics, self-efficacy, and wheelchair satisfaction were measured. Results were analyzed with multilevel regression for possible associations with wheelchair skills.

Results: No statistically significant changes were found in the ability and performance time scores of the Wheelchair Circuit over the first year after discharge. Age, lesion level, self-efficacy and wheelchair satisfaction showed a positive relationship with the Wheelchair Circuit scores. Change in wheelchair skills performance was not different between groups with different personal or lesion characteristics. Self-efficacy was positively related to changes in wheelchair skill performance over time ($p<0.02$).

Conclusion: Wheelchair skill performance, measured with the Wheelchair Circuit, did not change during the first year after discharge from inpatient rehabilitation. Improvement in wheelchair skill performance during that time was associated with higher self-efficacy perceptions.

Keywords: Manual wheelchair, Wheelchair skill learning, Wheeled mobility, Self-efficacy, Wheelchair satisfaction

INTRODUCTION

Community integration has been described as the ultimate goal in the rehabilitation of individuals following an injury or disability[1]. To function independently, manual wheelchair users must acquire a variety of wheelchair skills, to be able to deal with the physical barriers they will encounter in various environments in daily life[2]. Mastering wheelchair skills can make a difference between dependence and independence in daily life of people with spinal cord injury (SCI), who are primarily wheelchair users[3-4]. Studies showed that during the early phase of inpatient rehabilitation of persons with SCI, wheelchair skill performance improved significantly[5,6]. In a cross-sectional study, wheelchair skill performance of persons with SCI was found positively associated to participation (i.e. involvement in life situations) 1 year after discharge from inpatient rehabilitation[7]. At discharge from inpatient rehabilitation, persons with acute SCI can indeed propel their wheelchair and perform various wheelchair skills, such as negotiating curbs and transferring[6]; yet, other studies indicate that wheelchair users post rehabilitation may eventually still be rather immature in their wheelchair skills performances[8].

Following discharge from inpatient rehabilitation, SCI patients face the difficult challenge of adapting to life with a disability[9-10]. From previous studies it is known that, once discharged, persons with SCI are confronted with problems that negatively affect functioning[11]. In a study of Hammell et al.[8], concern was frequently expressed that “the therapists in the spinal units had no knowledge or awareness of what it really means to live with a disability in the community”. Frustration was directed to a generic rehabilitation process that aims to teach certain predetermined skills and is out of context with the specific and unique environment of the client, his values or lifestyle.

Reported problems post discharge include physical problems like pain[12,13,15,19,20], spasm[12–15,20], pressure sores [12–15,19–21], or bladder[13–15,19-20] and bowel problems[13,15,19,20]. The literature also mentions transportation and technical (wheelchair) problems[12,13,15,17,19], difficulties in care management[17,19], feelings of sadness[15,19] and lack of adequate housing[12,17,19]. These problems may directly influence the development of wheelchair skills performance and, therefore, lead to limitations in or even complete avoidance of participation in community.

Literature regarding changes in wheelchair skills performance in the first year after discharge from inpatient rehabilitation is lacking. It can be assumed that after being mobile in a wheelchair for 12 months post discharge, the level of wheelchair skill performance will have increased as a result of experience. On the other hand, the problems persons with SCI face in the first months post discharge from the rehabilitation center, may have led to a decrease in wheelchair skill performances.

The PAD model (Physical Activity behavior and functioning of people with a Disability) developed by Van der Ploeg et al.,[22] (p. 64) conceptualizes the possible relationship among physical activity, its determinants, and functioning in people with disabilities, taking into account personal and environmental factors. In the present study, wheelchair skill performance is the physical activity that may possibly affect participation in social activities. Demographic characteristics, SCI lesion level and completeness, and self-efficacy are the personal and lesion variables that were selected to analyze their relationship with wheelchair skill performance, while 'wheelchair satisfaction' represents the environmental factor that may effect changes in wheelchair skill performance over time.

Perceived self-efficacy is defined as "beliefs in one's capabilities to organize and execute the courses of action required for producing given attainments"[23]. The stronger an individual's sense of efficacy in physical tasks, the more positive is this person's perceived psychological well-being[24]. Increased self-efficacy in wheelchair skill performance may encourage wheelchair users with SCI to approach, persist, and persevere at executing wheelchair-related tasks that were previously avoided. In contrast, wheelchair users with low perceived self-efficacy in wheelchair skill performance may become inactive when facing daily physical challenges; evidently, perceived self-efficacy ultimately may affect changes in wheelchair skill performance over time[24].

"When assistive technology (i.e. a wheelchair) is successful in helping people maintain or regain control, important results are increased self-efficacy and decreased negative emotional reactions to disability. These effects in turn are hypothesized to enhance subjective well-being"[25]. This is the reason for choosing wheelchair satisfaction as a variable that might be related to changes in wheelchair skill performance over time as well.

The research objectives were: 1) to study possible changes in wheelchair skills in participants with spinal cord injury (SCI) between discharge and one year after discharge of inpatient rehabilitation; and 2) to determine whether these changes in wheelchair skill performance are related to lesion, personal characteristics and/or the subject's preceived self-efficacy and wheelchair satisfaction. The hypothesis was that wheelchair skill performance of persons with a SCI will improve during the first year after discharge from the rehabilitation center.

METHODS

The present longitudinal study was part of the Dutch research program "Physical Strain, Work Capacity, and Mechanisms of Restoration of Mobility in the Rehabilitation of Persons with Spinal Cord Injuries"[26] (www.scionn.nl). For the present study, persons with SCI were measured at the time of discharge from in-patient rehabilitation (t1) and 1 year after discharge from inpatient rehabilitation (t2). Eight Dutch rehabilitation centers specializing in the rehabilitation of persons with SCI participated in this research program. Eight trained research assistants conducted the measurements according to a standardized protocol. Persons were eligible to enter the program if they had an acute SCI, were between the ages of 18 and 67; were classified as A, B, C, or D on the American Spinal Injury Association (ASIA) Impairment Scale; were manual wheelchair-users; did not have a progressive disease or psychiatric disorder; and knew the Dutch language well enough to understand the goal of the study and the testing methods. Before being tested, subjects were extensively screened by a rehabilitation physician. Potential participants were not included if they had (1) cardiovascular diseases (the absolute contraindications as they are stated by the American College of Sports Medicine guidelines, or a resting diastolic blood pressure > 90 mmHg or a resting systolic blood pressure > 180 mmHg) or (2) severe musculoskeletal complaints of the upper limbs, neck, or back. To avoid influencing test results, participants were asked to consume only a light meal; to refrain from smoking, drinking coffee and drinking alcohol at least 2 hours before each measurement; and to void their bladder directly before testing. Further, a medical examination was performed and participants completed self-report questionnaires. Participants were tested in the rehabilitation centers in which they had been inpatients. All participants completed a consent form after they had been given information about the testing procedures. All tests and protocols were approved by the Medical Ethics Committee of the Institute for Rehabilitation Research (Hoensbroek, The Netherlands).

Wheelchair skill performance – The Wheelchair Circuit

The Wheelchair Circuit[27,28] is a test assessing wheelchair skill performance. The Wheelchair Circuit consists of eight different standardized tasks that are performed in a fixed sequence, on a hard and smooth floor surface, and on a motor-driven treadmill (Treadmill Giant, Bonte BV, Zwolle, the Netherlands). All participants used a standard test wheelchair, which was available in two seat widths: 0.42 m and 0.46 m (Sopur Starlight 622, Sunrise Medical GmbH, Germany). The eight tasks of the Wheelchair Circuit are: performing a figure eight; crossing a doorstep (height 0.04 m); mounting a platform (height 0.10 m); performing a 15 m sprint, 3 percent slope, 6 percent slope, 3 min wheelchair propulsion, and transferring from the wheelchair to a treatment table. For the slope tests, participants are asked to drive at the given slope for 10 s. The performance of the Wheelchair Circuit thus leads to two test scores: ability score and performance time score. For a more detailed description, see Kilkens et al.[27,28].

Ability Score. Each of the 8 test items that are performed adequately and independently are assigned as one point. Three items (crossing a doorstep, mounting a platform, and transferring) can also be scored "partially able" and can be given half a point. All points are summed to give an overall ability score. The ability score ranges from 0 to 8.

Performance Time Score. This score is the sum of the performance times of the figure eight and the 15 m sprint. Subjects who were not able to perform both the figure eight and the 15m sprint could not be assigned a performance time score.

Personal and lesion characteristics

Age and gender were registered at t1. At each test occasion (t1-t2), the lesion characteristics (level and completeness) were assessed by a physician according to the International Standards for Neurological Classification of

Spinal Cord Injury[33]. Neurological lesion levels below T1 were defined as paraplegia, while lesion levels at or above T1 were defined as tetraplegia.

Self-efficacy

Self-Efficacy was measured one year after discharge with the Self-Efficacy Scale (SES) developed by Sherer et al. (1982)[29]. The SES has been translated into Dutch by Bosscher and Drums (1989)[30]. A subscale on social self-efficacy was not translated and one item was deleted later due to ambiguous wording, and as a result, General Competency Scale with 16 questions remained (ALCOS-16). In this questionnaire, participants are asked to indicate on a 5-point Likert scale how much they agree or disagree with each statement concerning their ability to handle their current situation. The item scores are then added up to a total score ranging between 16 and 80. A high score means a high level of perceived general self-efficacy.

Wheelchair Satisfaction

To test wheelchair satisfaction, the Dutch version of the Quebec user evaluation of satisfaction with assistive technology questionnaire (D-quest) was administered 1 year after discharge[31]. In this valid and reliable instrument, the respondent is asked to rate his or her satisfaction with the daily used wheelchair with respect to 13 different aspects using a five-point scale. The scale ranges from 1 (not satisfied at all) to 5 (very satisfied). In this study, only general satisfaction with the wheelchair (question number 13) was analyzed. Scores 1 or 2 were considered as not satisfied (0) and scores > 3 were considered as satisfied (1).

Statistical analysis

Descriptive statistics (means ± SD) were applied to all variables. To determine whether wheelchair skill performance improved significantly 1 year post discharge**,** (research question number 1), a random coefficient regression analysis (MlwiN[32,33] program) was performed. The benefits of this method are that it accounts for the dependency of repeated measures within the same person; it is suitable when differences between rehabilitation centers are expected and it accounts for the hierarchical nature of the longitudinal data of the present study. In the longitudinal data set of this study, three levels of hierarchy are present: the repeated measurement (test occasion t1–t2) (level 1), which are grouped within individual participants (level 2), who are grouped in the rehabilitation centers (level 3). To answer the first research question, the ability score and performance time score were related to time, which was entered into the analyses as a categorical variable with the first measurement as reference (dummy t1-t2: t1=0, t2=1). To describe the relationship between personal/lesion characteristics and wheelchair skills, we first analyzed which of the independent variables were, in addition to the time-based model, univariately related to either the ability score or the performance time score). Apart from time, the independent variables were age (years), gender (male=1, female=0), lesion level (paraplegia=1, tetraplegia=0), and motor completeness of the lesion (complete=1, incomplete=0). To determine possible differences in the course of wheelchair skills between groups (age, gender, lesion level, completeness) over time, we added the interaction term time*group to the model.

To investigate associations of wheelchair skill performance with self-efficacy (ALCOS-16, Mean scores) or wheelchair satisfaction (yes=1, no=0), these scores were added to the basic model. For each predictor (i.e self-efficacy/ wheelchair satisfaction), the regression analyses reveals a standardized regression coefficient β, indicating the strength of the relationship of the predictor variable with the dependent variables ability and time.

Personal and lesion characteristics were added one by one to those models to investigate whether a significant interaction existed between all the independent variables and the time indicator variable (t1-t2), in order to investigate their possible confounding effect on the relation between self-efficacy or wheelchair satisfaction and changes in wheelchair skill performance. Variables that changed the regression coefficients of self-efficacy or wheelchair satisfaction by at least 10% were identified as confounders. All of the above regression models were analyzed separately for each of the two scores of the Wheelchair Circuit (Ability score and performance time score). Significance level was set as $p \leq 0.05$.

RESULTS

Participants

This study was based on a selection of 111 participants who performed the Wheelchair Circuit at the end of the rehabilitation and one year after. (Mean inpatient period was 177 ± 87 days, range 15-454 days). Since only two measurement occasions are involved we deemed it necessary to include only subjects who obtained scores on these two occasions, although not strictly necessary for multilevel regression analysis. Participants' mean age at t1 was 38.2 ± 13.8 years (range 18 – 67 years), and 80 participants (72%) were men. There were 76 participants with paraplegia, including 20 persons with a motor incomplete lesion, and 35 persons with tetraplegia, including 13 persons with a motor incomplete lesion.

Wheelchair skill performance

The mean and SD of the ability scores at t1 was 6.65±2.05 and at t2 6.66±2.16. Descriptive statistics of trends in the ability score over time showed that 16 persons declined (*n*=9 tetra, 8 persons who had a lower ability score at t2 (50%) were tested at the same rehabilitation center), 71 showed no change (*n*=13 tetra) and 24 (*n*=8 tetra) improved their ability score between discharge and 1 year after discharge from the rehabilitation center.

The mean and SD of the performance time scores at t1 was 23.22 ±13.28 sec. and 22.77±13.58 sec at t2. Descriptive statistics of the performance time score over time showed that 61 persons had a lower time score at t2 (i.e. improvement, 55%, *n*=19 tetra), 35 persons had a higher time score at t2 (i.e. deterioration, 31%, *n*=14 tetra) and 15 persons had the same time score at t1 and t2.

Despite the course of improvement in the time score between t1 and t2 indicated above, the multilevel regression analysis for the total group (research question 1) showed no significant changes in the ability scores and the performance time scores during the first year after discharge from inpatient rehabilitation (Table 1).

Personal and lesion characteristics

Ability score. Age was inversely related to the ability score, e.g., participants who are older in 10 years had on average 0.3 points lower ability scores (r=.42, p<.001). Participants with paraplegia had on average a 1.8 points higher ability score than those with tetraplegia (r=.60, p<.001). Gender or completeness of the injury were not related to the ability score. No significant interactions with time were found, indicating that the change over time in wheelchair skills in the year after discharge was not different between groups with different personal or lesion characteristics (Table 1).

Performance time score. A significant relation existed between age and performance time, indicating that 10 year older participants had on average a 2 seconds higher performance time score (r=.38, p<.001) than younger participants. Persons with paraplegia were on average 12.1 seconds faster than those with tetraplegia (r=.56, p<.001). No significant interaction terms between personal/lesion characteristics and time were found (Table 1).

Self-efficacy and wheelchair satisfaction

Self-efficacy had a significant relationship with the ability score (r=.33, p=.008) and the performance time score (r=.45, p=.004). Lesion level was a confounder for the relationship between self-efficacy and both wheelchair skill performance scores. However, after correcting for lesion level, self-efficacy still had a relationship with the course of wheelchair skill performance (ability score r=.58, p=.025, performance time score r=.65, p=.016) (Table 1).

Wheelchair satisfaction had a positive relationship with the ability scores, i.e. people who were more satisfied with their daily wheelchair, had on average 0.8 points higher ability scores (r=.41, p=.02), and those who were more satisfied with their wheelchair were on average 5.1 seconds faster (r=.43, p=.03). Lesion level of the SCI was a confounder for the relationship between wheelchair satisfaction and wheelchair skill performance for both test scores. However, in the final model, after correcting for lesion level, the relationships between wheelchair satisfaction and changes in the ability scores or the performance time scores were not significant (Ability score r=.46, p=.86, performance time score r=.65, p=.91).

Table 1: **Multilevel analysis of the relation between the outcomes 'ability' and 'performance time' and their determinants: 'subject characteristics', lesion characteristics, self-efficacy and wheelchair satisfaction'**

@ Basic model results of the multilevel analyses of the relations between the Wheelchair Circuit outcomes (Ability and Performance Time Scores) and Time (t1-t2) ;
* Model outcomes for each individual Personal / lesion characteristic in association with the Wheelchair Circuit outcomes (Ability and Performance Time Scores) (univariate models);
# Model outcome for possible interaction terms with time (t1-t2) of each of those personal / lesion characteristics with change in the Wheelchair Circuit outcomes over time;
** Final model outcome for interactions between time (t1-t2) and Self-efficacy or Wheelchair satisfaction after correcting for confounders (lesion level, completeness, age and gender)
Clearly, the model results for constant(c), t1-t2 and each personal/lesion characteristic will change with each continued model step; these changes are not shown below.

Factor	Ability score			Performance time score		
	β (S.E)	95% C	*P*	β (S.E)	95% C	*P*
@ Constant	6.600 (0.301)	-	-	23.299 (1.878)	-	-
t1-t2*	0.119 (0.235)	-.347-.585	0.61	0.117 (1.660)	-3.173-3.407	0.94
*** Age (y)**	-0.031 (0.008)	-.047- -.015	**<.001**	0.241 (0.060)	.122-.360	**<.001**
Gender	-0.306 (0.271)	-.843-.231	0.26	-0.178 (1.911)	-3.966-3.610	0.92
Lesion level	1.798 (0.224)	1.354-2.242	**<.001**	-12.588 (1.606)	-15.77--9.40	**<.001**
Completeness	-0.020 (0.254)	-.523-.483	0.93	-0.867 (1.829)	-4.492-2.758	0.63
Self-efficacy	0.035 (0.013)	.009-.061	**0.008**	-0.255 (0.087)	-.427--.083	**0.004**
Wheelchair satisfaction	0.776 (0.337)	.108-1.444	**0.023**	-5.158 (2.378)	-9.871--.445	**0.031**
# Age × t1–t2	-0.006 (0.016)	-.038-.026	0.70	0.002 (0.116)	-.228-.232	0.98
Gender × t1-t2	0.038 (0.533)	-1.018-1.094	0.94	-0.893 (3.730)	-8.286-6.50	0.81
Lesion level × t1-t2	-0.175 (0.441)	-1.049-.699	0.69	-1.247 (3.141)	-7.472-4.978	0.69
Completeness × t1-t2	0.010 (0.495)	-.971-.991	0.98	1.497 (3.543)	-5.525-8.519	0.67
****Self-efficacy…× t1-t2**	0.025 (0.011)	.003-.047	**0.025**	-0.184 (0.075)	-.333-.035	**0.016**
Wheelchair satisfaction…× t1-t2**	0.056 (0.319)	-.576-.688	0.86	-0.232 (2.284)	-4.759-4.295	0.91

S.E: Standard Error; 95% CI: 95% Confidence Interval. The regression coefficient of time dummy t1-t2 represents the change between t1 (=0) and t2 (=1). Gender was coded as male=1, female=0, lesion level as paraplegia=1, tetraplegia=0, motor completeness of the lesion as complete=1, incomplete=0, Self-efficacy (ALCOS-16, Mean scores), and satisfaction of the wheelchair as yes=1, no=0.

DISCUSSION

The preliminary assumption of this study was that wheelchair skill performance of person with a SCI will improve one year after discharge from the rehabilitation center. This study provides a follow-up to Kilkens et al.[5] (who studied improvement of wheelchair skills during inpatient rehabilitation), by focusing on the first year after discharge from inpatient rehabilitation and on two additional possible determinants of wheelchair skills: self-efficacy and wheelchair satisfaction. The assumption of the current study was that wheelchair skill performance of persons with SCI will improve during the first year after discharge from the rehabilitation center. However, the results of the study provided evidence of stabilization of wheelchair skills performance over the first year after discharge of inpatient rehabilitation. This lack of improvement might be explained by the difficulties and complications that people with SCI have to face and cope with during the first year after discharge from the rehabilitation center. The security of the rehabilitation center is replaced by a world where anxieties about home and family life, relationships, access, employment, care provision, finance, attitudes and isolation are all real threats[34].

A study by Bloemen-Vrencken and de Witte[11] showed that problems with informal care, pressure sores, unadapted environments and weight increase occurred and were most apparent after discharge. In contrast, the study by DeSanto-Madeya[35] examining the physical, emotional, functional, and social components of adaptation to spinal cord injury at 1 year and 3 years post-injury showed that "on average, Year 1 spinal cord injured individuals had considerably higher adaptation scores than spinal cord injured individuals at year 3. Based on these findings, one could speculate perhaps Year 1 spinal cord injured individuals are more hopeful that they will overcome their injury-imposed limitations than their Year 3 counterparts". Craig et al. stated that it may be that a minimum of 2 years is needed to achieve some stability in life, although this will vary from person to person"[36].

But the non-significant improvement in wheelchair skill performance could be also the result of a lesser suitability of the Wheelchair Circuit for testing wheelchair skill performances in post-acute rehabilitation phase of people with SCI. The Wheelchair Circuit consists of a selection of different possible wheelchair tasks and most relevant skills are included, yet, some tasks that may be relevant for participation in the community setting are not included in this test, for example, performing a wheelie (i.e. balancing on the rear wheel) is not tested. Furthermore, in this study, the ability score of the Wheelchair Circuit clearly showed a ceiling effect with a median score of 7.5 on a 0- to 8-point scale. It might be the outcome of the fact that most of the participants already reached the top level at the end of the rehabilitation program and could not further improve. However, it might also be the result of the use of a qualitative scale (pass/fail and partial pass scores), which might not be sensitive enough.

Personal and lesion characteristics

Age and lesion level were associated with the Wheelchair Circuit scores. These results are in accordance with those of other studies that found age inversely related to functional abilities after SCI[5,37], as well as with the studies that have shown relations between lesion level and functional outcome after inpatient rehabilitation[5,38,39]. Warschausky et al.[37] examined the recovery of the FIM motor scores in 142 subjects with SCI during inpatient rehabilitation. Unlike this study result, they found that changes in the FIM motor scores were significantly influenced by gender.

The absence of interaction between time, age, gender, SCI lesion level and completeness indicated that these variables did not influence the rate of change in wheelchair skill performance over a period of one year after discharge. As far as we know, no other studies described the longitudinal development of wheelchair skills performance one year after discharge from inpatient rehabilitation, and the few studies that were found in the literature included only self-report measures like the AM-PAC[40]; therefore, we could only compare our results with longitudinal studies that were conducted during inpatient rehabilitation.[5,41,42]. Taricco et al.[41] evaluated the impact of rehabilitative interventions on the functional status of SCI patients using the VFM (Valutazione Funzionale Mielolesi) test at the beginning and at the end of the rehabilitation program. Scores had significantly improved for persons with tetraplegia and those with a high level paraplegia only. Kilkens et al.[5] found that personal characteristics, lesion characteristics, and secondary complications significantly influenced the course of wheelchair skill performance between the start and discharge of inpatient rehabilitation. Middleton et al.[42] reported positive responsiveness to change over time in 5 mobility and locomotor items mainly in the group with a tetraplegia, while a ceiling effect was mentioned for the group with a paraplegia. These studies[5,42] showed that the largest improvement occurred during the first three months of the inpatient rehabilitation period. This fact may be suggestive for the current stabilization in wheelchair skill performance in the first year after discharge.

Self-efficacy and wheelchair satisfaction

The association between self-efficacy and the Wheelchair Circuit scores emphasizes the importance of psychological factors on learning new skills and reintegrating to the society[43]. Self-efficacy beliefs is defined as the confidence an individual has in performing a set of skills required to succeed in a specific task[44]. Self-efficacy influences choice of activities and motivational level, and contributes to the acquisition of knowledge and refinement of new abilities[23]. It is assumed that maximizing wheelchair skills and overall independency is also (and perhaps mainly) influenced by psychological and attitudinal factors rather than just disability-related factors. Therefore, in future studies, it is highly recommended to involve more psychological components, and to examine their relationships and their effect on learning wheelchair skills. Finding lesion level of the injury as a confounder may suggest that also in the case of a psychological variable as self-efficacy, wheelchair skills might be differently viewed by persons with tetraplegia and paraplegia.

The lack of relationships found between wheelchair satisfaction and wheelchair skill performance (after correcting for lesion level and completeness of the injury) is in accordance with de Groot et al. study[45]. This study examined the relationship between manual wheelchair users' satisfaction, and active lifestyle and participation in persons with SCI. In their study too, no relationship was found between the wheelchair-related aspects total satisfaction score and the activity and participation scores. Their finding that participants with an incomplete lesion were slightly more satisfied than those with a complete lesion, are supported by the fact that in the current study, completeness of the SCI was found as a confounder for the relationship between wheelchair satisfaction and wheelchair skill performance.

Study limitations

Apart from what has been said about the greater suitability of the Wheelchair Circuit to assess wheelchair skill performance during the acute phase of SCI rehabilitation rather than for post discharge individuals, the present study design needs also some consideration. The participants performed the Wheelchair Circuit in a standard wheelchair due to the necessity to ensure comparability of the measurements in the main longitudinal study in which persons with SCI are followed from the start of functional rehabilitation to one year after discharges. The experimental wheelchair is not individually optimized and the participants were not trained to use this wheelchair. Possibly, the participants would reflect better their wheelchair skills performances abilities had they been allowed to use their own wheelchairs.

Finally, one should bear in mind that the study investigated only the variables self-efficacy and wheelchair satisfaction besides personal and lesion characteristics, whereas SCI readjustments to community life are being influenced by many other physical and psychological factors that are beyond the scope of the current investigation. Also relevant pre-injury factors such as emotional history, belief about disability, perceived ability to cope and social support and active versus passive lifestyle must be studied in future research.

CONCLUSION

Manual wheelchair skill performance of persons with SCI, as measured with the Wheelchair Circuit, got improved, but not significantly, one year after discharge from inpatient hospital. Improvement in wheelchair skill performance during that time was associated with higher self-efficacy perceptions. People with SCI should further be stimulated to maintain and improve wheelchair skills performance after discharge from rehabilitation center. Incorporate strategies to enhance self-efficacy during wheelchair skills interventions might result in better outcome.

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Chapter 4

Development of a new scale for perceived Self-Efficacy in manual Wheeled Mobility: A pilot study

Fliess-Douer O, van der Woude LH, Vanlandewijck, YC, (2011). Development of a new scale for perceived Self-Efficacy in manual Wheeled Mobility: A pilot study. *Journal of Rehabilitation Medicine,* 43: 602–608.

ABSTRACT:

Objective: To study the psychometric qualities of the 'perceived Self-Efficacy in Wheeled Mobility scale'.

Design: Questionnaires.

Subjects: Forty-seven wheelchair users with spinal cord injury (elite athletes *n*=25, recreational *n*=22, from 6 different countries).

Method: Based on literature, expert's and wheelchair user's comments, a new 'Self-Efficacy in Wheeled Mobility Scale (SEWM)' was developed. Internal consistency (split-half and Cronbach's alpha) and concurrent validity (correlating the 'Self-Efficacy in Wheeled Mobility Scale' with the 'Generalized perceived Self-Efficacy Scale (GSE)' and the 'SCI Exercise Self-Efficacy Scale' (ESES) were assessed. To evaluate the construct validity, age, lesion level and completeness and time since injury between groups of participants and their total scores were statistically compared.

Results: Cronbach's alpha for the SEWM was 0.91, internal consistency was r=0.90. Significant correlations between pairs of scales of the entire sample (SEWM-ESES: 0.60; SEWM-GSE: 0.50 (p<0.05; n=47, 2-tailed) and of the sub-group comparison (SEWM-ESES recreational r=0.61; elite r=0.73), demonstrated fair construct and concurrent validity of the SEWM.

Conclusions: SEWM seems reliable and valid in manual wheelchair users with a SCI. A larger and more diverse sample is needed to support psychometric qualities of the SEWM scale.

Key words: Self Efficacy, Hand rim wheelchair, mobility, spinal cord injury

INTRODUCTION

Rehabilitation interventions following spinal cord injury (SCI) require major adaptations in physical capacity, and the development of skills and functional behavior. An important change that many patients with SCI (80%) will encounter in early rehabilitation is the transition from being a walking individual to a manual wheelchair user[1]. Therefore, one of the main rehabilitation interventions will focus on wheelchair skills and manual wheeled mobility (WM), since wheelchair skills can make the difference between dependence and independence in daily life for people with SCI[2]. In addition, there are many wheelchair skills tests applied to measure wheelchair skill performance and perceived WM abilities[3]. It can be expected that there is a positive relationship between the level of manual wheelchair skill performance and participation in persons with SCI[4] (participation as defined in the International Classification of Functioning, Disability and Health (ICF) classification system)[5]. Accordingly, changes in WM behaviour can be demonstrated, for example, from unsuccessful to successful completion of a certain wheeled mobility task, or from unsteadiness or fear of falling, to improved balance function while moving around with a wheelchair.

Self-efficacy beliefs are defined as the confidence an individual has in performing a set of skills required to succeed in a specific task; perceiving self-efficacy is a major factor influencing behavior change, especially when complex skills need to be learned[6]. Perceived self-efficacy influences choice of activities and motivational level, and contributes to the acquisition of knowledge and refinement of new abilities[7]. Perceived self-efficacy also influences individual judgments, effort, resilience, life choices, and perseverance in the face of difficulties[8]. In short, when perceived self-efficacy is high, people will generally put forth more effort, set higher goals, and persevere through obstacles.

The Attitude, Social Influence and Self-Efficacy model (ASE) is being used as a basis for interventions on behavioral change in the context of health and a physically active lifestyle[9]. Van der Ploeg et al.[10] suggested integrating the ASE model into the ICF Model of Functioning, Disability and Health[5], which describes the multidimensional aspects of functioning, disability and health in the context of environmental and personal factors.

It was recommended that the ingredients of the ASE model are instrumental to the rehabilitation outcome of physical activity stimulation in the context of rehabilitation programs[10]. As a result, a new model, describing the relationship between Physical Activity behavior and functioning of people with a Disability (PAD model) was proposed. The PAD model conceptualizes the possible relationship among physical activity, its determinants, and functioning in people with disabilities, taking into account personal and environmental factors[11]. Since WM is a physical activity that may possibly affect participation, and perceived self-efficacy is a meaningful "personal factor" that determines physical activity behavior, the PAD model is chosen as the theoretical framework underpinning the current study (Fig. 1).

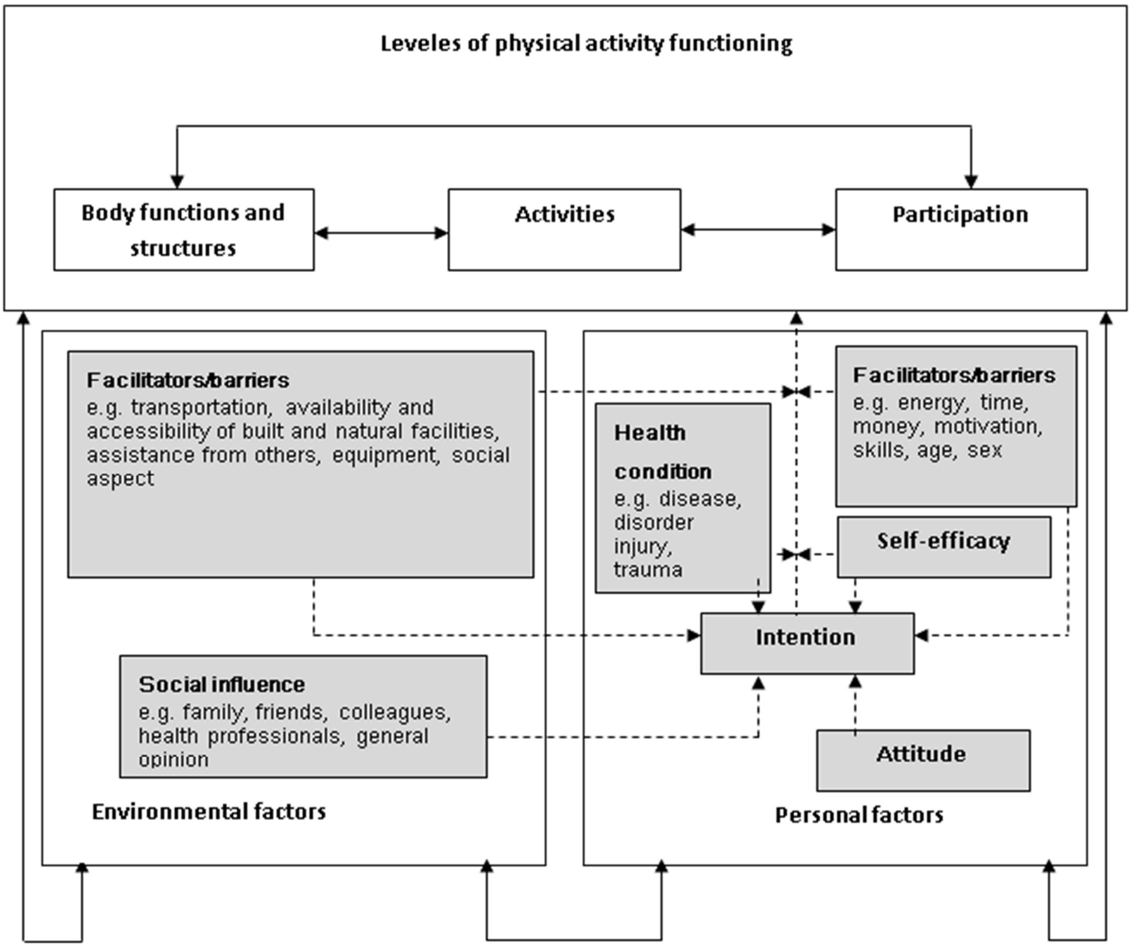

Figure 1: **The Physical Activity for people with a Disability (PAD) model**

The Physical Activity for people with a Disability (PAD) model, an integrated model of physical activity behavior and its relation with functioning and disability. The framework of the International Classification of Functioning, Disability and Health (ICF) model is shown by the white and grey boxes and the solid arrows, while the determinants of physical activity behavior are shown in the pink boxes. The dashed arrows in the PAD model represent the pathway through which these factors determine physical activity, although not all possible pathways and relations are shown in the model. Most of the dashed arrows also work in the opposite direction and, as shown in the general framework, all components of the integrated model more or less interact with each other. van der Ploeg et al, 2004[10]

Despite the different studies on wheelchair skills and the development of different test batteries for measuring WM performances[3], the role of personal traits on wheelchair skill acquisition has not been dealt with in detail. Nor has the perceived self-efficacy in wheeled mobility and wheelchair skills been evaluated comprehensively.

Perceived self-efficacy scales can be general and cover a broad spectrum of activities, such as the 'Generalized perceived Self-Efficacy' scale[12] which is presumably, the most recognized perceived self-efficacy scale. Other perceived self-efficacy scales can be domain specific, such as the 'SCI Exercise Self-Efficacy Scale'[13]. To summarize, there are two levels of perceived self-efficacy scales; *global* self-efficacy scales, and *domain-specific* self-efficacy scales, which measure either the level of *functioning* or *assessing specific skills*. Domain-specific scale items are constructed at an intermediate level of difficulty and are better predictors than global tests[6].

The current study was designed to develop a new clinimetrically reliable and valid scale for perceived Self-Efficacy in manual Wheeled Mobility (SEWM). Further objectives were:

- To test the internal consistency of the new SEWM scale among a group of wheelchair users with a SCI;
- To evaluate the concurrent validity in comparing the outcomes of the new SEWM scale (Appendix 1) with the existing 'Generalized perceived Self-Efficacy Scale' scale (GSE, Appendix 2) and the 'SCI Exercise Self-Efficacy Scale' (ESES, Appendix 3);
- To evaluate the construct validity by means of associations between the SEWM scale scores and basic characteristics such as age, activity level, lesion level, completeness of spinal cord injury and time since injury.

METHODS

The initial item pool for the SEWM was based on the GSE[12] and the ESES[13]. The GSE consists of 10-items and is assessing a general sense of perceived self-efficacy on a 4-point-Likert scale (minimum score 0, maximum score 40). It aims to predict coping with daily hassles as well as adaptation after experiencing all kinds of stressful life events. In samples from 23 nations, Cronbach's alphas ranged from 0.76 to 0.90, with the majority in the high 0.80s. Criterion-related validity is documented in numerous correlation studies where positive coefficients were found with favorable emotions, dispositional optimism, and work satisfaction. Negative coefficients were found with depression, anxiety, stress, burnout, and health complaints. The weakness of the GSE is that, as a general measure, it does not tap specific behavior change. Therefore, in most applications it is necessary to add a few items to cover the particular content of the survey or intervention[14].

The ESES[13] is a recently developed tool measuring SCI exercise self-efficacy in community-dwelling adults who participate in structured exercise programs as well as assessing exercise self-efficacy beliefs in occasional as well as habitual exercisers with spinal cord injuries. Similar to the GSE, the ESES consists of 10 items assessed in 4 point-Liker scale (minimum score 0, maximum score 40). Preliminary findings indicated that the ESES is a reliable instrument with high internal consistency (Cronbach's alphas 0.92, n=368) and satisfying content and construct validity[13]. The current research team reviewed and modified the items of these scales for presumed relevance to the SCI population and WM skills[3]. Arguments and discussions for the enhancement of acceptable face validity of the scale were performed based on a literature review and on experts' and wheelchair user's comments. The wheelchair users represented different lesion levels (three people), and the professional experts were two physiotherapists and two adapted physical instructors who are working for many years with spinal cord injury patients. They were invited to review the scale with regard to item content, clarity, relevance and format. Finally, 10 items were selected and constituted the 4-point Likert-scale SEWM. This generated a similar structure to both scales, the GSE and the ESES. For instrument design, the following definition of ICF for (wheeled) mobility was adopted: "Moving around using equipment: moving the whole body from place to place, on any surface or space, by using specific devices designed to facilitate moving or create other ways of moving around, such as with skates, skis, or scuba equipment, or moving down the street in a wheelchair or a walker"[5].

The SEWM scale was originally developed in English and translated to Dutch and Hebrew by psychologists who were experts in the field and spoke both languages fluently, following a bi-directional translation procedure.

Design

Participants, who after verbal explanation consented to participate in the evaluation study, received an informed consent form, a personal information form, the GSE, ESES and the new SEWM. The SEWM scale instructs respondents to rate how confident they are with regard to the virtual performance of specific and general WM skills on a 4-point Likert scale (1 = not at all true, 2 = rarely true, 3 = moderately true, 4 = always true).

Data collection and sample characteristics

The SEWM was tested in a group of 47 wheelchair users with SCI (paraplegic, lesion level T4 to L4, male/female ratio: 42/5). Eventually, two subgroups were discerned. The first group comprised 25 elite wheelchair basketball players from 6 countries: UK, USA, Belgium, The Netherlands, Greece and Israel. The questionnaires for this group were completed during the preliminary European wheelchair basketball tournament in Badajoz, Spain (2008) and in a joint training camp of team Great Britain and team Israel during the preparations for the 2008 Paralympics. The questionnaires were also passed to the Chicago wheelchair basketball college team. A second group of 22 individuals, participating in different recreational activities, also completed the scale. This group comprised people with a SCI from Belgium (a recreational activities group from KU Leuven, Faculty of Kinesiology and Rehabilitation Sciences) and from Israel (Tel-Aviv “veterans house” (*Beit-Ha’Lochem*)). The recreational activities of these participants are described in Table 1.

Statistical procedures

Descriptive statistics, internal consistency, concurrent and construct validity analyses were conducted for the whole sample and for the two subgroups (elite athletes/recreational) separately, using SPSS 15.0 (SPSS Inc., Chicago, USA). Internal consistency of the scale was determined by computing Cronbach’s alpha and Split-half (Spearman–Brown) correlation coefficients.

Concurrent and construct validity was obtained by correlating the total scores of the SEWM with the total scores of the GSE and the ESES in the same populations. Statistical significance was set at $p<0.05$. To support findings, regression analysis (predictive ability) of the SEWM and the ESES was performed. Basic demographic variables (age, lesion level, completeness of SCI, and time since injury) were statistically compared between both groups of participants, and a statistical comparison of their total scores on the SEWM scale was carried out. This procedure serves as another means to evaluate construct validity of the scale. Age was compared between groups by means of the *t*-test applied following Levene's test for equality of variances; for lesion level comparison, Pearson Chi-Square test was used; a comparison between participants with complete and incomplete SCI was performed with Fisher's exact test; and for comparison of time since injury, a non-parametric Mann-Whitney test was applied. Regression analysis (R-square) was used to test the correlations between SEWM total scores and the independent variables age, and time since injury. The non-parametric Mann-Whitney test was used to test the relationship between the SEWM total scores and completeness of SCI (complete/incomplete), and between lesion levels (high-level paraplegic/low-level paraplegic).

Table 1: **Subjects characteristics (*n*=47)**

		n	**DATA**
General	Total	47	UK 3, Greece 4, Israel 19, Holland 5, Belgium 13, USA 3
	Male	42	
	Female	5	
	Age		Mean = 38.2 ±13.9 Range = 18-75
	Time since injury		Range 2 – 52 , Mean = 16.9 ±13.1
	Completeness		Complete – 32, Incomplete – 12, Missing data – 3
	Lesion Level		T4 – L4
Subgroups			
Level of Activity	Elite	25	International level wheelchair basketball players
	Recreational	22	Fitness room 3, Art (drawing, sculpting) 4, Swimming 7, Billiard 4, Hand bikes -4
Age	Elite		Mean = 31.7±8.7
	Recreational		Mean = 45.6±15.2
Completeness	Elite		Complete – 18, Incomplete – 5, Missing data – 2
	Recreational		Complete – 14, Incomplete – 7, Missing data – 1
Lesion level	Elite		> T12 – 11, ≤T12 – 11, Missing data – 3
	Recreational		> T12 – 8, ≤T12 – 14
Time since injury	Elite		Mean = 14 ±9.9
	Recreational		Mean = 20.1 ±15.7

*The number indicates the *n* in each category

RESULTS

Only SCI, who were daily manual wheelchair users, were allowed to participate in the pilot study. Participants' demographic and clinical characteristics are presented in Table 1. At this stage of the development of the scale, only persons with paraplegia were involved in the study. Descriptive Statistics (means, standard deviations, and range of scores) for all three perceived self-efficacy scales are presented in Table 2. Percentage of maximal values of all three scales is presented in Table 3.

Internal Consistency

Item descriptive statistic of the SEWM for the two groups was preformed (Table 4). Cronbach's alpha of the entire sample (n=47) was 0.91 for the SEWM and 0.88 and 0.85 for the ESES and GSE. High internal consistency of the SEWM was confirmed in split-half (equal Length Spearman–Brown 0.90), as shown in Table 5. Performing internal consistency examination for the 10 items of the SEWM of the elite athletes group only (n = 25), showed lower correlations for two items (item 8 and 9) with the total score (Cronbach's alpha of the elite athlete group was 0.81, shown in Table 6).

Table 2: **Descriptive Statistics of all perceived self-efficacy scales for the entire sample and for the 2 groups separately**

	n	**Min.**	**Max.**	**Mean**	**SD**
GSE - total score	47	25	40	35.5	3.9
ESES - total score	47	18	40	34.3	4.8
SEWM - total score	47	14	40	34.7	6.0
GSE - total score [a]	25	28	40	36.4	3.7
ESES - total score [a]	25	25	40	35.6	4.1
SEWM - total score [a]	25	26	40	37.2	3.4
GSE - total score [b]	22	25	40	34.5	4.1
ESES - total score [b]	22	18	40	32.9	5.2
SEWM - total score [b]	22	14	40	31.9	7.0

[a] Athletes group, [b] Recreational group

SD: standard deviation; GSE: Generalized Perceived Self-Efficacy Scale; SEWM: Self-Efficacy in Wheeled Mobility Scale

Group comparisons a and b: GSE p= 0.10, ESES p=0.48, SEWM p=0.002

Table 3: **Percentage of maximal value (40)**

	GSE = 40	**ESES = 40**	**SEWM = 40**
	Frequency *n* (%)	**Frequency *n* (%)**	**Frequency *n* (%)**
Yes	38 (81)	39 (83)	35 (74.5)
No	9 (19)	8 (17)	12 (25.5)
Total	47 (100)	47 (100)	47 (100)

Yes = 40, No < 40

Table 4: **item descriptive statistic of the SEWM for the 2 groups**

	Recreational (*n*=22)	**Athletes (*n*=25)**	**All sample (*n*=47)**
SEWM items	**Mean (SD)**	**Mean (SD)**	**Mean (SD)**
I can overcome barriers and challenges regarding wheeled mobility skills if I try hard enough	3.36 (.90)	3.68 (.69)	3.53 (.80)
I can find means and ways to be independently mobile, using my wheelchair in everyday life setting	3.59 (.50)	3.72 (.54)	3.66 (.52)
I can accomplish tasks that require independent wheelchair mobility such as ascending sidewalks and ramps	3.05 (1.00)	3.72 (.54)	3.40 (.85)
When I am confronted with obstacles to wheelchair mobility, I can find solutions to overcome them	3.23 (.87)	3.72 (.54)	3.49 (.75)
I can overcome mobility barriers and challenges even when I am tired	3.14 (.83)	3.56 (.58)	3.36 (.74)
I can be independently mobile with my wheelchair even when I am depressed	3.36 (.79)	3.64 (.64)	3.51 (.72)
I can be mobile with my wheelchair without the support of my family or friends	3.59 (.59)	3.84 (.47)	3.72 (.54)
I can motivate myself to carry out a difficult wheeled mobility skill such as descending an escalator (moving stairs)	2.45 (1.26)	3.60 (.76)	3.06 (1.17)
I can learn new skills of wheeled mobility without the help of a therapist or trainer	3.05 (1.13)	3.88 (.33)	3.49 (.91)
While using my wheelchair, I can usually handle whatever comes my way	3.05 (.90)	3.80 (.41)	3.45 (.77)
Total score	31.9 (7)	37.2 (3.5)*	34.7 (6)*

* Since the mean is lower than the median, it is the case of a skewed right distribution (negative skew, standard deviation is inflated).

Table 5: **Equal-Length Spearman-Brown Split half of the SEWM items**

	Value
Cronbach's Alpha	0.91
Part 1 (items 1-5)	0.90
Part 2 (items 6-10)	0.80
Correlation Between Forms	0.81
Spearman-Brown Coefficient	
Equal Length	0.90

Table 6: **Internal consistency (alpha) of SEWM items**

Group		Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
Recreational *n*=22	**Item 1**	28.5	39.4	0.81	0.91
	Item 2	28.3	44.4	0.70	0.92
	Item 3	28.8	38.8	0.77	0.92
	Item 4	28.6	38.7	0.91	0.91
	Item 5	28.7	39.6	0.86	0.91
	Item 6	28.5	42.3	0.63	0.92
	Item 7	28.3	43.9	0.65	0.92
	Item 8	29.4	36.6	0.73	0.92
	Item 9	28.8	39.9	0.57	0.93
	Item 10	28.8	39.4	0.81	0.91
Elite Athletes *n*=25	**Item 1**	33.5	9.3	0.55	0.80
	Item 2	33.4	9.1	0.82	0.77
	Item 3	33.4	9.5	0.68	0.78
	Item 4	33.4	9.3	0.76	0.77
	Item 5	33.6	9.8	0.52	0.80
	Item 6	33.5	9.1	0.66	0.78
	Item 7	33.3	9.7	0.71	0.78
	Item 8	33.6	11.6	-0.02*	0.87
	Item 9	33.3	11.5	0.18*	0.83
	Item 10	33.4	10.7	0.43	0.81

* Items with lower correlation with the total score

Concurrent validity

There was a statistically significant correlation between both pairs of scales (Spearman Correlation SEWM and GSE = 0.50; SEWM and ESES = 0.60 (p< 0.05; n=47, 2-tailed). Correlations between the two scales (SEWM and ESES), among recreational vs. elite athletes, showed lower values for the recreational sample (recreational: 0.61; elite athlete =0.73). Explained variance among the scales in the athlete group were higher, compared to the non-athletes group (SEWM vs. ESES: R-Square Non-athletes =0.38, elite athletes = 0.53; SEWM Vs GSE: R square Non-athletes = 0.14, elite athletes = 0.44). These results demonstrate explained variance (predictive ability SEWM-ESES) of 53% among the elite athlete subgroup (Figure 2).

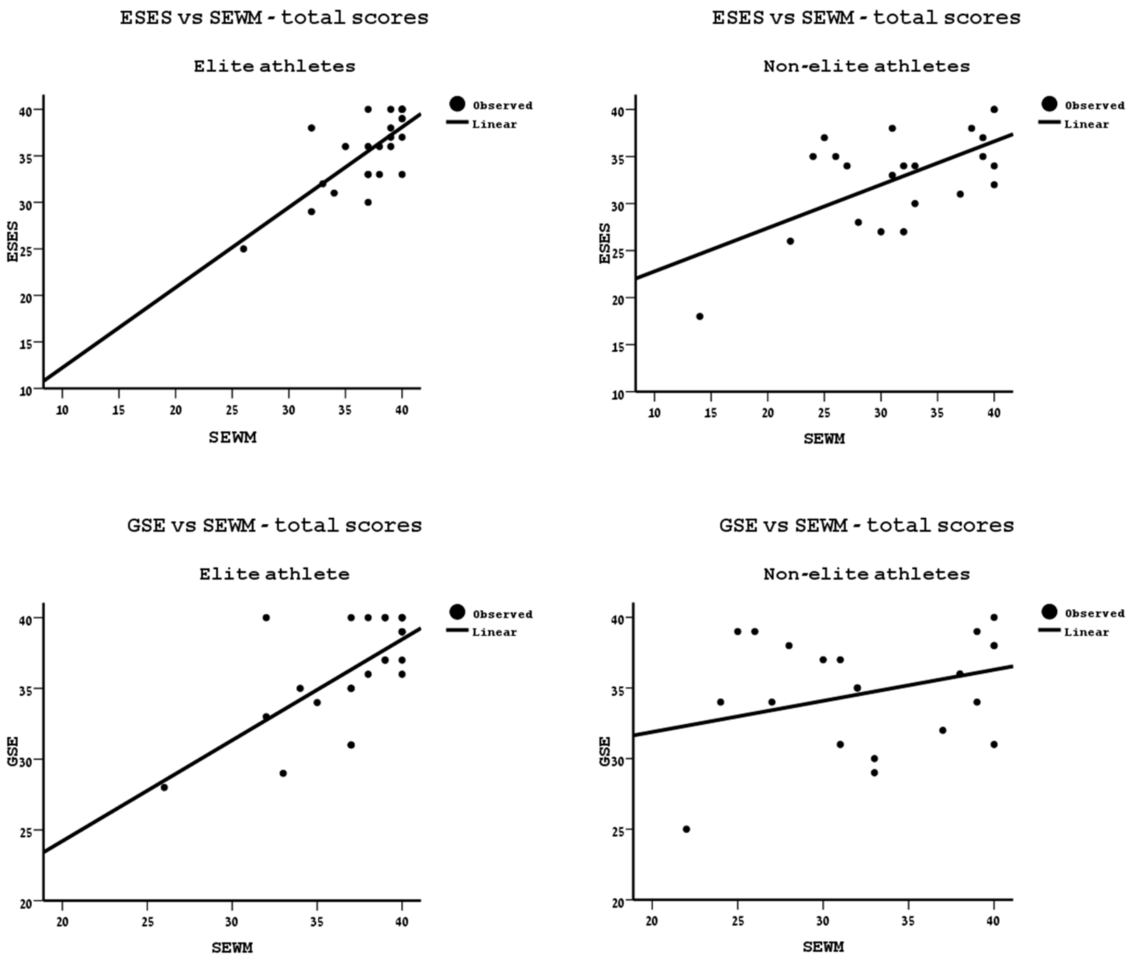

Figure 2: **predictive ability (percentage of explained variation**

The ability to predict ESES and GSE from SEWM for elite and non-elite athletes. The solid lines represent the linear regression. The percentages of explained variations (R2) are: ESES, elite athletes 53.3%; ESES, non-elite athletes 37.9%; GSE, elite athletes 44.3%; GSE, non-elite athletes 14.1%. SEWM: Perceived self-efficacy in Wheeled Mobility scale; ESES: Exercise Self-Efficacy Scale; GSE: Generalized Perceived Self-efficacy Scale.

Construct validity

There were no statistically significant differences between the athletes group and the recreational group in terms of *lesion level, completeness* of injury and *time since injury*. *Age* of the elite athletes group (Mean 31.7, SD 8.7) was significantly lower than in the recreational group (Mean 45.6, SD 15.2, p=0.001). To control for the possibly confounding effect of the lower age in the elite athletes group, in the comparison of the total SEWM score between the two groups, an ANCOVA model was constructed with age serving as covariate. This analysis confirmed the higher values of the score in the elite group. (The adjusted mean is greater by 4.4 points in the elite group compared to the unadjusted of 5.3).

A regression of the SEWM score on the athlete's age showed a statistically significant decrease in SEWM score with age (a slope of -0.14, p=0.02). A regression of the SEWM score on time since injury variable, showed a statistically significant decrease in SEWM scores with time (a slope of -0.09, p=0.04). Additionally, a strong positive correlation was found between age and time since injury (r=0.74), indicating multicollinearity situation in which the two variables (age and time since injury) in a multiple regression model are highly linearly related.

A stepwise backwards regression of SEWM scores on both variables, showed that controlling for age, the time since injury is not significant (p=0.65) although negligible in magnitude the association was positive (Table 7).

There was no difference in SEWM total scores between athletes with complete lesions (35.4±4.4) and incomplete lesions (31.8±8.9, non-parametric Mann-Whitney test p=0.47). However, there were statistically significant differences between SEWM scores of different lesion levels; low paraplegics (n=19 ≤T12) had statistically significant higher SEWM scores compared to high paraplegics (n=25 >T12) (p=0.02).

Table 7: **Stepwise Regression of SEWM on 'age' and 'time since injury'**

	Unstandardized Coefficients B±SE	***t***	***p***
Model 1			
(constant)	40.565±2.657	15.267	0.000
Age	-0.174±0.091	-1.902	0.064
Time since injury	0.045±0.097	0.462	0.65
Model 2			
(constant)	40.120±2.454	16.348	0.000
Age	-0.14±0.060	-2.357	0.02

*In model 1, both variables are entered and it shows that controlling for age, the variable time since injury is not significant and its coefficient is positive.
Model 2 shows that the dominant variable associated with the decrease in SEWM is age. SE: standard error

DISCUSSION

The stronger an individual's sense of efficacy for physical tasks, the more positive his or her perceived psychological well-being[15]. Some support for perceived self-efficacy as a mediator of an individual's wheelchair mobility behavior was found by Hedrick in 1985[16], who reported that participation in tennis by wheelchair mobile adolescents increased their tennis perceived self-efficacy. Hedrick also examined whether success experience in tennis can impact on other competency domains; perception of physical competence was enhanced, but no impact on social or cognitive competence was noted. Greenwood et al.[17], who investigated psychological well-being of wheelchair tennis participants and wheelchair non-active participants, found a significant correlation between wheelchair mobility perceived self-efficacy and wheelchair tennis perceived self-efficacy. The wheelchair mobility scale that was used in Greenwood's study was formulated according to Bandura's[6] recommendations, and consisted of 16 items. Greenwood's scale measured the individuals' strength of perceived self-efficacy by having participants indicate on a scale from 0 to 100, their perceived confidence in completing each task. However, in the Greenwood et al. study, no details are provided on the scale items and on the statistical procedures to validate and to confirm the reliability of the scale. Therefore, it was deemed necessary to develop a new reliable and valid perceived self-efficacy scale in wheeled mobility for SCI.

Reliability of the Self-Efficacy in Wheeled Mobility Scale

Current preliminary findings indicate that the SEWM is an instrument with high internal consistency. However, an internal consistency examination for the 10-items of the SEWM for the elite athletes group separately, showed lower correlations for two items (#8 and #9) with the total score. Especially item # 8 ("I can motivate myself to carry out a difficult wheeled mobility skill such as descending an escalator (moving stairs)" lowered the internal consistency of the scale. When these two items were removed, the consistency increased substantially. The reason that item #8 lowered the internal consistency of the scale could be related to the fact that this item contains a specific and rather challenging task (descending an escalator). Item #9 includes negative expression (I can learn new skills of wheeled mobility without the help of a therapist or trainer), which might also reduce the consistency. In order to lessen the influence of these two items, it is advised to rephrase the sentences. In order to keep the 10 items set, a suggestion for a new phrasing may be, for item 8: "I can motivate myself to carry out a difficult and challenging wheeled mobility skill" and for item 9: "I can learn new skills of wheeled mobility by myself". Obviously this requires follow up analysis.

The concurrent validity of the Self-Efficacy in Wheeled Mobility scale

Regarding the concurrent validity, the moderate size of the correlations indicate a reasonable fit of the SEWM with the ESES and the GSE scales, and allows the conclusion that the measure does not measure the same elements as the other scales.

In the present study, correlation investigations showed higher scores for the SEWM vs. ESES than for the SEWM vs. GSE. It can be explained by the fact that the ESES and the SEWM were both developed specifically for SCI populations, yet the SEWM is the more specific perceived self-efficacy scale measuring self-efficacy in wheeled mobility perceptions of people with SCI. These results support initial assumptions that self-efficacy perceptions are domain-specific, which means that an individual can have high perceived self-efficacy for the skills associated with one activity and at the same time express lower perceived self-efficacy for other domains of activity[18]. For instance, some individuals may be highly certain that they can accomplish tasks that require independent wheelchair mobility such as ascending sidewalks and ramps and simultaneously be completely unconfident for their teaching skills. In the current study, nearly 80% reached a maximum score in all three scales; this is probably due to the specific sample of athletes involved in this study. Yet, compared to the GSE and the ESES, less participants reached the maximum score for the SEWM scale, supporting the specificity of the SEWM.

The construct validity of the Self-Efficacy in Wheeled Mobility scale

A psychometrically well-built perceived self-efficacy in wheeled mobility assessment tool may find future applications in measuring self-efficacy beliefs in wheelchair skills performances of SCI. It can be applied in structured enhancement WM programs and also in assessing progress in WM levels in occasional as well as regular activity for people with SCI. Construct validity is the degree to which the scores of the SEWM are related to variables that are hypothesized or known to be related to WM.

One could easily argue with the relevancy of testing construct validity of the SEWM scale with variables that are known to be related to WM rather than with variables that are related to self-efficacy; from previous studies it is known that self-efficacy in a specific domain is related to actual performance[19,] Horn et al.[20] measured self-efficacy in 105 persons with SCI 12 months after discharge from an acute-care setting, using a 7-item scale based on the items from the Functional Independence Measure (FIM). They found a high correlation (r.84) between their self-efficacy measure and FIM Motor items on which it was based. If Self efficacy in WM is related to WM performance, and lesion level, motor completeness of the lesion, age and activity levels are directly related to the performance of wheelchair skills in persons with SCI[21], it was assumed, that also in the case of perceiving self-efficacy in wheeled mobility, when the construct validity of the SEWM is good, these determinants will be significantly associated with the scale scores. Supporting the construct validity of the SEWM, age was found to be inversely related to the SEWM scores. Also low paraplegics had higher SEWM scores compared to high paraplegics (lack of control of abdominal muscles). This was the case in previous actual WM skills performance tests, in SCI populations[21]. Therefore, it can be cautiously suggested, that following an extended study with a heterogeneous population and with a larger sample, the SEWM has the potential to be used as a predictor tool for actual WM skills performance. Furthermore, as reported in the literature, for most WM skills test development processes, construct validity was based on correlating the new WM skill test with the FIM instrument[3]. The SEWM scale presented here perhaps can be used as a substitute to the FIM for WM test development purpose.

Differences in activity levels, as detected in this study, are supporting the construct validity of the new scale; there is a clear tendency for higher scores of all three scales in the elite athletes group; when individuals perform a task, they judge their performance and develop self-efficacy beliefs about their mastery of the task. "Individuals review their capabilities for a desired behavior through acting-out or performing the skills necessary to achieve the behavior successfully (enactive mastery experience), mastery experience is a very influential self-efficacy source"[7]. If individuals successfully complete a desired behavior, such as ascending a ramp without incident, then they experience a sense of mastery for that behavior. The best way to increase self-efficacy perceptions, using enactive mastery, is through extensive practice[22]. With regard to sport self-efficacy beliefs, past success in training and competition are important antecedents of perceived self-efficacy[7]. The elite wheelchair basketball players who participated in our study probably gained more WM experiences and competent through practices, and therefore hold higher beliefs about their WM capabilities.

Limitations and future work

The current sample (*n* = 47, paraplegics only) is rather small. 75% reaching maximal score in the current study result (a ceiling effect), is a great limitation and could be explained by the fact that all the participants who completed the SEWM were able to take a part in a community based activity (sport or recreational level). A future examination should consider a larger sample, including participants from all scope of life such us persons with tetraplegia, inactive individuals, man and women etc.

In addition, the SEWM scale in the present study was compared to two other scales but it is still unclear to what extent it correlates with measures of the actual WM performances. In the present study exercise behavior was only recorded through self-report. The SEWM scale needs to be further tested and evaluated in a sample whose WM performances are assessed more comprehensively.

A future study, should also test if the SEWM can be limited to a shorter list of items; although 10-item's scale is rather short and it doesn't take long to complete the questionnaire, the high internal consistency confirmed in this study may suggest a possibility for items reduction.

In the future, test-retest examination is advised to be implemented. Methodologically, reliance on split-half methods to determine the stability of the instrument has been criticized due to the multiple ways the two halves can be formed based on the set of items. Future study is needed to determine the scale's usefulness and sensitivity for detecting change in perceived self-efficacy as a result of WM interventions for people with SCI.

Including in the sample participants from six countries representing three different continents is a particular strength of the study. In conclusion**,** the findings indicate that the SEWM is an instrument with high internal consistency. Slightly rephrasing items 8 and 9 is advisable to further improve internal consistency. Concurrent validity was supported mainly in the sub-group investigation, while construct validity was supported by the 'age' factor and 'activity level', but not for 'time since injury'. Further study with a larger more varied sample including people with tetraplegia was conducted at the Beijing Paralympic games and supported the clinimetric characteristics of this scale.

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Appendix 1 - **Self-Efficacy in Wheeled Mobility Scale (SEWM)**

Please tell us how confident you are with regard to carrying out the wheeled mobility skills below. (*Please check only one box for each question*)

I am confident that:	***Not at all true***	***Rarely true***	***Moderately true***	***Always true***
I can overcome barriers and challenges regarding wheeled mobility skills if I try hard enough	❑	❑	❑	❑
I can find means and ways to be independently mobile, using my wheelchair in everyday life setting	❑	❑	❑	❑
I can accomplish tasks that require independent wheelchair mobility such as ascending sidewalks and ramps.	❑	❑	❑	❑
When I am confronted with obstacles to wheelchair mobility, I can find solutions to overcome them	❑	❑	❑	❑
I can overcome mobility barriers and challenges even when I am tired	❑	❑	❑	❑
I can be independently mobile with my wheelchair even when I am depressed	❑	❑	❑	❑
I can be mobile with my wheelchair without the support of my family or friends	❑	❑	❑	❑
I can motivate myself to carry out a difficult wheeled mobility skill such as descending an escalator (moving stairs)	❑	❑	❑	❑
I can learn new skills of wheeled mobility without the help of a therapist or trainer	❑	❑	❑	❑
While using my wheelchair, I can usually handle whatever comes my way	❑	❑	❑	❑

Appendix 2 - **Generalized Self-Efficacy Scale (GSE)***

Please check only one box for each question:

I am confident that:	*Not at all true*	*Rarely true*	*Moderately true*	*Always true*
I can always manage to solve difficult problems if I try hard enough	❑	❑	❑	❑
If someone opposes me, I can find the ways and means to get what I want	❑	❑	❑	❑
I am certain that I can accomplish my goals	❑	❑	❑	❑
I am confident that I could deal efficiently with unexpected events	❑	❑	❑	❑
Thanks to my resourcefulness, I can handle unforeseen situations	❑	❑	❑	❑
I can solve most problems if I invest the necessary effort	❑	❑	❑	❑
I can remain calm when facing difficulties because I can rely on my coping abilities	❑	❑	❑	❑
When I am confronted with a problem, I can find several solutions	❑	❑	❑	❑
If I am in trouble, I can think of a good solution	❑	❑	❑	❑
I can handle whatever comes my way	❑	❑	❑	❑

*Schwarzer, R., & Jerusalem, M. **(1995)**. Generalized Self-Efficacy scale. In J. Weinman, S. Wright, & M. Johnston, *Measures in health psychology: A user's portfolio. Causal and control beliefs* (pp. 35- 37). Windsor, UK: NFER-NELSON.

Appendix 3 - **SCI Exercise Self-Efficacy Scale***

Please tell us how confident you are with regard to carrying out regular physical activities and exercise. (Please check only one box for each question)

I am confident:	*Not at all true*	*Rarely true*	*Sometimes true*	*Always true*
that I can overcome barriers and challenges with regard to physical activity and exercise if I try hard enough	❑	❑	❑	❑
that I can find means and ways to be physically active and exercise	❑	❑	❑	❑
that I can accomplish the physical activity and exercise goals that I set	❑	❑	❑	❑
that when I am confronted with a barrier to physical activity or exercise I can find several solutions to overcome this barrier	❑	❑	❑	❑
that I can be physically active or exercise even when I am tired	❑	❑	❑	❑
that I can be physically active or exercise even when I am feeling depressed	❑	❑	❑	❑
that I can be physically active or exercise even without the support of my family and friends	❑	❑	❑	❑
that I can be physically active or exercise without the help of a therapist or trainer	❑	❑	❑	❑
that I can motivate myself to start being physically active or exercising again after I.ve stopped for a while	❑	❑	❑	❑
that I can be physically active or exercise even if I had no access to a gym, exercise training, or rehabilitation facility	❑	❑	❑	❑

Chapter 5

Reliability and validity of perceived "self-efficacy in wheeled mobility" scale among elite wheelchair-dependent athletes with a spinal cord injury

Fliess-Douer O, Vanlandewijck YC, van der Woude LH, (2012). Reliability and validity of perceived "self-efficacy in wheeled mobility" scale among elite wheelchair-dependent athletes with a spinal cord injury. *Disability and Rehabilitation*, Accepted for publication.

ABSTRACT

Purpose: To study the reliability and validity of the perceived "self-efficacy in wheeled mobility" scale among elite athletes with a spinal cord injury (SCI).[1]

Method: During the Beijing Paralympics, 79 participants with SCI completed the SCI Exercise Self-Efficacy Scale (ESES), the perceived Self-Efficacy in Wheeled Mobility scale (SEWM) and the perceived wheeled mobility (WM) at present Visual Analog Scale (VAS). Sample included athletes from 18 countries and subcategorized by gender, lesion level/completeness and type of sports. Reliability and concurrent validity were determined.

Results: SEWM Cronbach's alpha was 0.905. High internal consistency was confirmed in Split-half correlation coefficient (r=0.87). Validity was supported by significant correlations between SEWM and ESES total scores (r=0.64, p<0.05), and between SEWM and WM VAS scores (r=0.60; p<0.001). Subgroups analyses showed that athletes with tetraplegia showed significantly lower WM self-efficacy levels than paraplegics. There was a significant difference in perceived WM self-efficacy between athletes who participated in dynamic wheelchair sports and those who participated in non-wheelchair sports (p<0.03).

Conclusions: The SEWM is a reliable and valid scale among Paralympic athletes with SCI. Findings confirmed a significantly higher perception of self-efficacy in WM among athletes who participated in dynamic wheelchair sports.

Key words: Spinal cord injury, Self-Efficacy in Wheeled Mobility scale (SEWM), Wheelchair sports, Validity

[1] The latest version of the SEWM scale in different languages, can be freely obtained at: www.scionn.nl/inhoudp28.htm

INTRODUCTION

On a daily basis, manual wheelchair users with a spinal cord injury (SCI) encounter many wheelchair-related barriers and obstacles, which can limit their participation in both leisure and professional activities. According to the International Classification of Functioning Disability and Health (ICF), the concept of wheeled mobility (WM) is a subcategory of the category "Moving around using equipment"[1]. For individuals with SCI, it refers to their ability to move around, using a wheelchair, in different and quite challenging environments. Given that approximately 80% of the persons with SCI will remain dependent on a wheelchair for the rest of their lives[2], acquiring wheelchair skills has to be considered as an important part of SCI rehabilitation. The link between wheelchair skills performance and participation was demonstrated in a cross-sectional study by Kilkens et al.[3]. The level of WM is thus indicative of the involvement in daily activities, which is a crucial factor for the quality of life. Therefore, increasing wheeled mobility and skill performance will have a great impact on the functional independence of SCI patients, and mastering wheelchair skills can make the difference between dependence and independence in daily life for people with SCI[4].

Functional outcomes after SCI vary from person to person, depending on many factors: the level and completeness of the injury, neurologic recovery, associated complications (contractures, spasticity), amount of rehabilitation training, age, body size, weight, motivation, family support and financial status[5]. It is assumed that maximizing WM and achieving overall independence are influenced by attitudinal factors such as self-efficacy, rather than by disability-related factors alone[6].

Perceived self-efficacy is defined as "beliefs in one's capabilities to organize and execute the courses of action required for producing given attainments"[7]. The stronger an individual's sense of efficacy in physical tasks, the more positive is this person’s perceived psychological well-being [8]. Increased self-efficacy in WM may encourage wheelchair users with SCI to approach, persist, and persevere at WM related tasks that were previously avoided. In contrast, wheelchair users with low perceived self-efficacy in WM may become inactive when facing daily physical challenges; this may ultimately hinder their participation and quality of life.

Self-efficacy scales, such as The Generalized Perceived Self-Efficacy Scale (GSE) of Jerusalem & Schwarzer[9], which is presumably the most recognized self-efficacy scale, can be general and cover a broad-spectrum. Other self-efficacy scales can be domain specific, such as the Perceived Exercise Self-Efficacy Scale of Sallis et al.[10], which measured the confidence levels of individuals when participating in a physical activity under various conflicting situations. An example of a self-efficacy scale in the rehabilitation domain is The Self-efficacy Scale for Activities of Daily Living (SEADL), developed by Adnan et al.[11]. This scale is very detailed and assesses perceived self-efficacy in specific daily tasks (e.g., combing hair, eating with fork and spoon, etc.). Domain-specific self-efficacy scales assesses self-efficacy in relation to specific skills and are constructed at an intermediate level of difficulty and are better predictors of actual performance than are global tests[12].

Only a limited number of studies was found in the international literature, supporting perceived self-efficacy as a mediator of wheelchair mobile individuals' behaviour. As might be expected, athlete's sport self-efficacy likely transferred to feeling of efficacy for ADL. Hedrick reported that participation in tennis by wheelchair mobile adolescents increased their tennis self-efficacy[13]. Greenwood et al.[8], who investigated the psychological well-being of wheelchair tennis participants and of wheelchair non-tennis participants, found a significant correlation between perceptions of wheelchair mobility self-efficacy and perceptions of wheelchair tennis self-efficacy. In Adnan et al. study[11], athletes expressed much stronger self-efficacy, in particular for transferring from wheelchair to bed and seat, compared to non-athletes. Rushton et al.[14] recently assessed the content validity of a 62-item Wheelchair Use Confidence Scale (WheelCon-M). This comprehensive scale aims for clinicians as a method for identifying individuals who have low confidence with wheelchair use, and it is composed of six areas: negotiating the physical environment, activities performed using a manual wheelchair, knowledge and problem solving, advocacy, managing social situations and managing Emotions. This scale's validity and reliability measures were not yet published.

This study aims to test the reliability and validity of a recently developed SEWM scale[15]. A suggestion that was raised after reviewing the results of a pilot study (SCI, *n*=47, wheelchair basketball players vs. recreational level participants, persons with paraplegia only), was to rephrase two of the items on the scale[15].

The Paralympic games in Beijing 2008 provided an opportunity to retest the validity and the reliability of the new version of the SEWM scale in a large international group of participants with tetraplegia and paraplegia. Complementary to the pilot study sample, the current study population consists of elite Paralympic athletes, forming an international sample of wheeled mobility experts. These athletes represent different types of sports, different level of SCI and different socio-cultural and linguistic backgrounds. If differences will be exposed in this group of athletes, it can provide support for the scale sensitivity; therefore it was decided to compare perceived self-efficacy in WM in subgroups of these wheelchair-dependent elite athletes.

The main research questions were: (a) what is the internal consistency and the concurrent validity of the SEWM among a group of elite Paralympian wheelchair dependent SCI? And (b) will perceived self-efficacy in WM among athletes who compete in dynamic wheelchair sports be significantly different from that of athletes competing in static or non-wheelchair sports?

METHODS

Based on a literature survey, experts' comments, the opinions of SCI wheelchair users representing different lesion levels, and the results and conclusions of the pilot study[15], ten items of the SEWM scale were recomposed (Appendix 1). The SEWM scale was originally developed in English and translated into French, Spanish, Dutch, Chinese and Hebrew by external experts in the field, who speak both source and target languages fluently, using a bi-directional (forward and backward) translation procedure[16]. The SEWM scale instructs respondents to rate how confident they are with regard to the performance of WM skills on a 4-point Liker scale (1 = *not at all true*, 2 = *rarely true*, 3 = *moderately true*, 4 = *always true*). Consisting of only 10 items, the SEWM is easy to administer and interpret which is a major strength of the tool. Marking 10 items is feasible even for individuals with limited hand function, as in the case of tetraplegia.

Design

This study was conducted in accordance with the guidelines of the Declaration of Helsinki, and was approved and supported by the International Paralympic Committee, Sport Science Committee (IPC SSC).

The participants who consented to participate in this study received questionnaires to fill out. The cluster of questionnaires included: a consent form, a personal information form, the Self-efficacy in Wheeled Mobility Scale[15] and the SCI Exercise Self-Efficacy Scale (ESES)[17]. The latter is a recently developed tool for measuring SCI exercise self-efficacy among community-dwelling adults who participate in structured exercise programs[17]. The ESES consists of ten items assessed using 4 point-Liker scale (minimum score 0, maximum score 40). Preliminary findings indicated that the ESES is a reliable instrument with high internal consistency (Cronbach's alpha 0.92, *n*=368) and satisfactory content and construct validity.

After completing the two self-efficacy scales, the participants were asked to answer the question: "How would you describe your level of wheeled mobility skills performance today?" Responses were provided by placing a vertical mark (| or X) on a 10 cm line, (0-10 WM VAS - visual analog scale[18], where 0 is equal to "*poor*" and 10 is equal to "*excellent*").

Data collection and sample characteristics

In order to increase response and minimize the interference in the athletes' schedule during the Paralympic games, several approaches were combined: during the first days of the games. The researchers met each team's managers (men and women's wheelchair basketball and wheelchair rugby teams), and briefly explained the study's aims and distributed the questionnaires. The researchers clarified that only athletes with SCI who are permanently wheelchair dependent can participate in the study. Mobile telephone numbers of the managers were collected for sending reminders by text message (SMS). Besides contacting the teams' managers, the research team handed questionnaires to wheelchair basketball and wheelchair rugby players, off court between games. In individual sports (wheelchair tennis, archery, fencing etc.), the research team handed the questionnaires to SCI athletes while they were watching other matches and during their free time at the international zone in the Paralympic village. To ensure anonymity, completed questionnaires were returned by team managers or individual participants through a mailbox at the polyclinic in the athletes' Paralympic Village.

Sample

Approximately 250 questionnaires were passed to team managers and to individual athletes. Ninety-four questionnaires were returned, but only 79 were sufficiently completed, i.e., with the two self-efficacy scales fully completed.

Statistical procedures

The statistical analyses were performed using SPSS (version 15.0, SPSS Inc., Chicago Ill, USA).

SEWM analysis

Internal Consistency of the scale was determined by computing Cronbach's alpha and Split-half (Spearman Brown) correlation coefficients[19]. Concurrent Validity was obtained by correlating the SEWM with the 10-item ESES in the same populations. Regression analysis (predictive ability) of the SEWM and the ESES was performed. Finally, a correlation between the SEWM, total score and a WM VAS scale, indicating their WM level at present, was analysed. Statistical significance was set at $p<0.05$. As suggested by Colton[20], correlations ranging from 0.00 to 0.25 indicate little or no relationship; those from 0.25 to 0.50 suggest a fair degree of relationship; values of 0.50 to 0.75 are moderate to good; and values above 0.75 are considered good to excellent.

Athlete subgroups

Different categorizations for athlete subgroups were determined, following: 1) Gender (male/female); 2) Lesion characteristics: level (paraplegic vs. tetraplegic) and completeness (complete vs. incomplete) and 3) Type of sports: static wheelchair sports (e.g., archery, shooting) vs. dynamic wheelchair sports (e.g., wheelchair tennis); wheelchair sports vs. non-wheelchair sports (e.g., swimming, rowing); individual dynamic wheelchair sports (e.g., wheelchair tennis) vs. team wheelchair sports (e.g., wheelchair basketball, wheelchair rugby). A Mann-Whitney test of the SEWM scores was used to investigate whether there were significant differences between pairs of above mentioned subgroups ($p<0.05$).

RESULTS

Participants

The study sample included 49 male and 30 female athletes from 18 countries and 14 sports disciplines. The sample included 64 persons with paraplegia and 15 with tetraplegia, whose ages ranged from 14 to 53 years (33±8.18y), Time since injury varied, ranging from 3 to 31 years (15.5±6.63), and time participating in Paralympics sports ranged from 1 to 22 years (10±5.5). Sample characteristics are presented in Table 1.

Table 1: **Sample characteristics**

		n	**Remarks**
General	Total	79	Australia 2, Canada 5, Colombia 1, France 8, Great Britain 13, Germany 2, Greece 3, Hungary 1, Ireland 3, Israel 9, Italy 1, Morocco 1, New Zealand 2, Romania 1, Spain 3, Sweden 3, USA 20, Zimbabwe 1
	Male	49	
	Female	30	
Lesion level	Paraplegic	64	T1 – T7: *n*=17 T8 – T12: *n*=32 L1 – L4: *n*= 12 Missing data: *n*=3
	Tetraplegic	15	C5 – C8: *n*=15
Completeness	Complete	46	missing data *n*=8
	Incomplete	25	
Paralympic sports category	Wheelchair dynamic team sports	33	Wheelchair rugby 6, Wheelchair basketball 27
	Wheelchair dynamic individual sports	15	Wheelchair tennis 8, Racing 5, Hand cycling 2
	Wheelchair static sports	15	Archery 6, Throwing 4, Fencing 1, Shooting 1, Table tennis 3
	Non- wheelchair sports	16	Equestrian 1,Rowing 2, Swimming 12, Sledge Hockey 1

Mean scores and *SDs* of the entire sample and the different subgroups, obtained using the two self-efficacy scales, are presented in Table 2.

Table 2: **Descriptive statistics: results of the entire sample and of the subgroups on the two self-efficacy scales**

Characteristic		SE Scale	*n*	Mean	SD	Min	Max
Total sample		ESES	79	35.87	3.68	25	40
		SEWM	78	36.65	4.22	24	40
Gender:	Male	ESES	49	35.67	3.74	27	40
		SEWM	49	36.55	4.33	24	40
	Female	ESES	30	36.20	3.62	25	40
		SEWM	29	36.83	4.12	25	40
Lesion:	Tetra	ESES	15	35.47	2.50	32	40
		SEWM	15	33.80	4.65	24	40
	Para	ESES	61	36.03	3.81	25	40
		SEWM	60	37.40	3.72	24	40
Sports type:	Team wheelchair	ESES	32	36.69	3.09	29	40
		SEWM	31	37.9	3.23	27	40
	Individual wheelchair sports	ESES	15	35.27	4.18	28	40
		SEWM	15	37.40	2.56	31	40
	Individual static sports	ESES	15	35.47	3.48	27	40
		SEWM	15	36.33	3.42	28	40
	Non-wheelchair sports	ESES	16	34.94	4.36	25	40
		SEWM	16	33.69	6.30	24	40

SD: standard deviation; ESES: SCI Exercise Self-Efficacy Scale; SEWM: Self-Efficacy in Wheeled Mobility Scale

Reliability

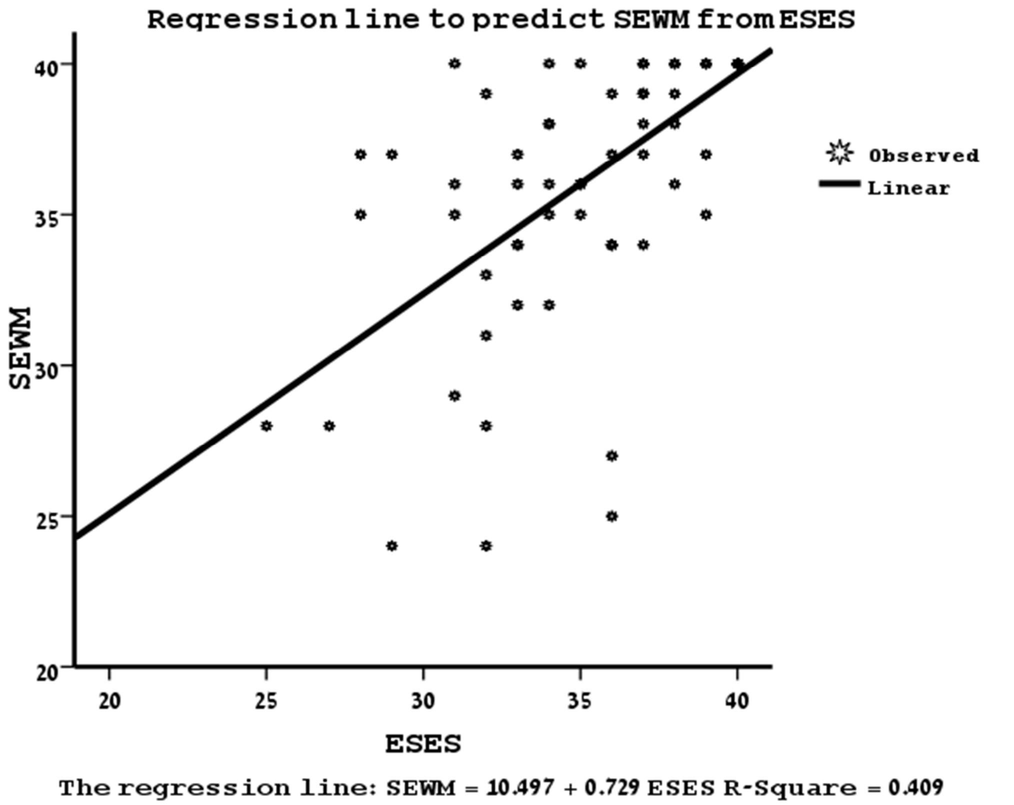
Cronbach's alpha of the entire sample was 0.905 for the SEWM and 0.809 for the ESES. The internal consistency results of the SEWM items are presented in Table 3. High internal consistency of the SEWM was confirmed in the Split-half method (EQ Length Spearman Brown r=0.870).

Table 3: **Internal consistency (Cronbach's alpha) of SEWM items (*n*=79)**

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
I can overcome barriers and challenges regarding wheeled mobility skills if I try hard enough	32.15	11.51	0.59	0.78
I can find means and ways to be independently mobile, using my wheelchair in everyday life setting	31.99	12.26	0.52	0.79
I can accomplish tasks that require independent wheelchair mobility such as ascending sidewalks and ramps.	32.19	11.54	0.52	0.79
When I am confronted with obstacles to wheelchair mobility, I can find solutions to overcome them	32.27	11.04	0.58	0.78
I can overcome mobility barriers and challenges even when I am tired	32.38	10.98	0.55	0.78
I can be independently mobile with my wheelchair even when I am depressed	32.44	10.91	0.47	0.79
I can be mobile with my wheelchair without the support of my family or friends	32.39	11.39	0.35	0.80
I can motivate myself to carry out a difficult and challenging wheeled mobility skill	32.32	10.68	0.47	0.79
I can learn new skills of wheeled mobility by myself	32.09	12.13	0.43	0.79
While using my wheelchair, I can usually handle whatever comes my way	32.65	9.59	0.58	0.78

Validity

Concurrent validity was determined by correlating the SEWM with the ESES total scores. There was a statistically significant correlation between the two scales (r=0.64, p<0.05). Concurrent validity between the SEWM total score and the "wheeled mobility at present" VAS score (total VAS mean score = 8.69±1.5) was r=0.60 (p<0.001). Regression analysis (predictive ability - percentage of explained variance) conducted on the total score and the complete participant sample (SEWM vs. ESES) showed R^2 = 0.409 (Fig. 1 and Table 4).



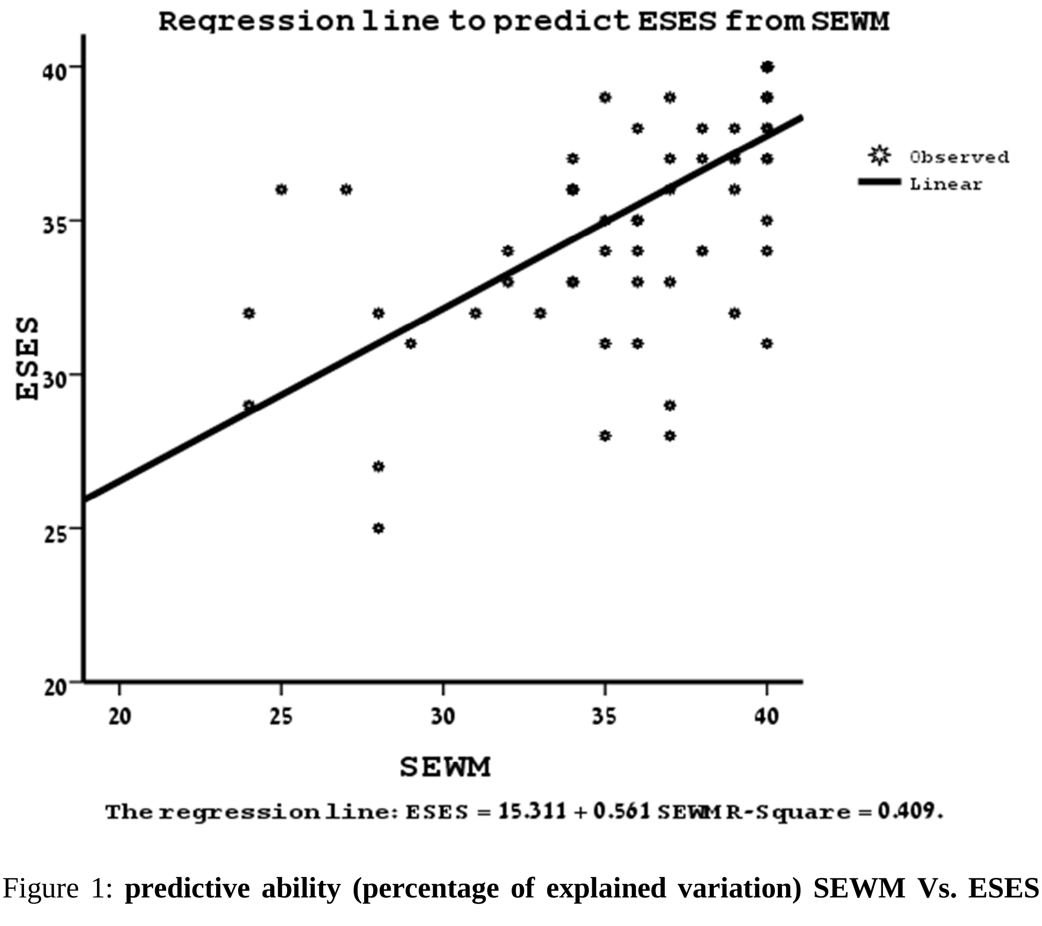


Figure 1: **predictive ability (percentage of explained variation) SEWM Vs. ESES and ESES Vs. SEWM**

Table 4: **The analyses of variance and coefficient values for the regression analyses**

ANOVA					
	Sum of Squares	df	Mean Square	F	Sig.
Regression	561.862	1	561.862	52.602	< 0.000001
Residual	811.792	76	10.681		
Total	1373.654	77			

a Predictors: (Constant), ESES - total score
b Dependent Variable: SEWM - total score

Coefficients					
Variable	**Unstandardized Coefficients**		**Standardized Coefficients**	**t**	**Sig.**
	B	**Std. Error**	**Beta**	**B**	**Std. Error**
(Constant)	10.497	3.625		2.895	.005
ESES - total score	.729	.101	.640	7.253	<0.000001

a Dependent Variable: SEWM - total score

ANOVA					
	Sum of Squares	df	Mean Square	F	Sig.
Regression	432.226	1	432.226	52.602	< 0.00001
Residual	624.492	76	8.217		
Total	1056.718	77			

a Predictors: (Constant), SEWM - total score
b Dependent Variable: ESES - total score

Coefficients					
Variable	**Unstandardized Coefficients**		**Standardized Coefficients**	**t**	**Sig.**
	B	**Std. Error**	**Beta**	**B**	**Std. Error**
(Constant)	15.311	2.853		5.366	.000001
SEWM - total score	.561	.077	.640	7.253	< 0.000001

a Dependent Variable: ESES - total score
Unstandardized coefficients (B) = the regression coefficients
Std. Error = standard errors of the regression coefficients

Athlete subgroups

There was a significant difference in perceived self-efficacy in WM between athletes with a paraplegia and tetraplegia (Table 5). Also between athletes who participated in team and individual wheelchair sports vs. those who participated in non-wheelchair sports a significant difference was seen. No significant differences were found among gender and complete/incomplete spinal cord injury or any of the other sports subgroup divisions.

Table 5: **A comparison between athlete subgroups**

Characteristic	SEWM total score Mann-Whitney U	Asymp. Sig. (2-tailed)
Gender comparison (*n*=79)**:**		
Male vs. Female	682.5	0.76
Lesion comparison (*n*=71)**:**		
Tetraplegia vs. Paraplegia	216.5	0.001
Type of sport comparison (*n*=64)**:**		
Team and individual wheelchair sports vs. non-wheelchair sports	236	0.03
Type of sport comparison (*n*=63)**:**		
Team and individual wheelchair sports vs. static sports	256	0.12
Type of sport comparison(*n*=48)**:**		
Team wheelchair sports vs. individual wheelchair sports	188.5	0.28

DISCUSSION

The main goal of this study was to test the statistical properties of the revised version of the recently developed SEWM scale[15]. This study confirmed the good reliability and construct and concurrent validity of the SWEM among a group of elite Paralympians at the Beijing games. The international sample of 79 participants from 18 different countries and 5 different continents strengthen its statistical results.

Findings confirmed the reliability of the SEWM by the high internal consistency of the scale's items. Compared to the pilot study[15], the internal consistency of the SEWM in this study was higher (In this study, Cronbach's alpha was 0.90; in the pilot study, Cronbach's alpha among the wheelchair basketball players was 0.81). These findings demonstrate the benefit of rephrasing items 8 and 9, and the necessity of conducting the current international study among a larger group of elite athletes.

Concurrent validity

First, based on the absolute mean values of both scales, athletes in the current study had high perceptions about their self-efficacy in wheeled mobility. SEWM mean scores were slightly higher than those of the ESES. The Paralympians who participated in this study, probably increased their WM abilities through their sports training and experiences, and therefore hold high beliefs about their WM competency. Similar to the pilot study results, regression analysis and correlation analyses values were higher for the SEWM compared to those of the ESES (Pilot study, SEWM vs. ESES: recreational r =0.61; elite athlete r =0.73). This can be explained by the fact that while both scales were developed specifically for the SCI population and both scales can be applied in the process of promoting an active life style for wheelchair users, the SEWM nevertheless is a more specific self-efficacy measure for WM.

Similar to the pilot study results, the moderate correlations indicate a reasonable fit of the SEWM with the ESES scale (also given the explained variance of 41%), and allows the conclusion that the measure is specific enough, and that it does not measure the same elements as the other scale.

Athlete subgroups

Type of sport

The two self-efficacy scales revealed higher WM self-efficacy perceptions among athletes who participate in dynamic (team and individual) wheelchair sports. The best way to increase self-efficacy, using enactive mastery, is through extensive practice[21]. The higher SEWM scores for these dynamic sports athletes (mainly wheelchair basketball and wheelchair rugby players) may be explained by more WM experiences and competences gained through practice, compared to those who participate in non-wheelchair sports or in static sports. Therefore, dynamic sports athletes were more confident about their WM capabilities. However, it is impossible to determine whether the athletes who joined dynamic wheelchair sports initially felt more competent in WM than did their static-sports peers and therefore chose this sports type, or if they joined dynamic sports and then became highly competent in WM, as a result of their practice. According to Bandura's theory[7], it might be an example for bi-directional influences. The direction of an influence is not mutually exclusive; it can go both ways. Thus, encouraging wheelchair users to join dynamic wheelchair sports, even for a short period of time, in order to improve WM performance is a logical conclusion based on this study's findings.

Similar to the current study, the pilot study results showed significantly higher self-efficacy perceptions for the more active group[15]. However, the comparison was made between two quite different characteristic wheelchair user groups (wheelchair basketball players vs. recreational level participants). In the current study, reliability and validity scores for the SWEM among the rather homogenous group of elite Paralympians, seems to further support and strengthen the psychometric quality of the SEWM scale. Greenwood et al.[8], found a significant correlation between perceptions of wheelchair mobility self-efficacy and perceptions of wheelchair tennis self-efficacy. However, this study lacks information regarding both the scale items and the statistical procedures undertaken to establish the validity and reliability of the tool.

Lesion level comparison

Since the pilot study sample did not include participants with tetraplegia, the current study, revealing significant differences between athletes with paraplegia and (the rather small group of) athletes with tetraplegia in terms of perceived self-efficacy in wheeled mobility, provides a valuable feedback to the researchers for future studies focusing on wheeled mobility related aspects. These significant differences support the results of other studies which focus on different variables related to functioning after SCI. Yet, the literature provides little information about the relation between lesion level on the one hand and wheelchair mobility on the other hand. In Kilkens et al. "Wheelchair Circuit" test[22], persons with paraplegia performed better than persons with tetraplegia. Also Janssen et al.[23], who studied physical strain during the performance of wheelchair tasks in persons with long-standing SCI has found that persons with tetraplegia experienced significantly higher levels of strain during task performance, than persons with paraplegia. In a recently published literature review of WM assessment tools[24], it was stated that previous tests failed to differentiate between levels of performance. Many tools exist for measuring WM in generalized wheelchair user populations. As a result, "ceiling or floor effects were the consequence of lack of precision and the ability of an instrument to detect meaningful changes in level of performance at the upper or lower ends of the scale"[24]. The current study results suggest that also in the case of a psychological variable as self-efficacy, wheelchair skills might be differently viewed by persons with tetraplegia and paraplegia. This may indicate that while testing actual WM performance, different levels of tasks difficulty may be required for participants with tetraplegia or paraplegia in order to enhance test responsiveness in these two subgroups. Middleton et al.[25] tested the psychometric properties of the Moorong Self-Efficacy Scale (MSES). The MSES is a 16-item scale rating confidence in performing everyday activities on a 7-point Likert scale. This new scale was designed for individuals with SCI and samples items across a wide range of relevant life domains, i.e., functional, social, leisure, and vocational activities. However, this scale is lacking any WM specific item. Unlike the current study result, in Middleton's study, there were no significant differences between paraplegics and tetraplegics in perceived self-efficacy.

SCI Motor completeness

No significant differences were found for motor completeness of the lesion, neither in the pilot study nor at the present study results. There are two possible explanations for this result. First, all participants were wheelchair dependent. This implies that, in participants with incomplete lesions, the spinal cord was nevertheless severely damaged. The distinction in functioning between persons with motor complete and persons with motor incomplete lesions is therefore less evident. Secondly, it could be that the completeness of the lesion is not related to perceived self-efficacy in WM, as reported in other perceived self-efficacy studies involving individuals with disabilities[25, 26].

Gender differences

Males are often reported to have higher scores on self-efficacy and related constructs [26]. Unexpectedly, and perhaps partially because the sample size was somewhat unbalanced (Females: n = 30; Males: n = 49), there were no gender differences in perceived self-efficacy in WM in the current study. This may be due to the fact that the females participated in this study were top Paralympian athletes, with high WM capabilities, resulting in a high perceived self-efficacy in WM and thereby to a low gender difference.

Study limitations

The current sample of a convenience sample of n = 79, included top athletes with SCI only and cannot be representative of the entire SCI athlete population or the general SCI population. The low return rate of questionnaires (less than 33%) should also be mentioned. It could be explained in several ways: during the Paralympic games, athletes are focusing on the most important sports event of their lives. It is logical that research and questionnaires would not be their highest priorities during these days.

The SEWM scale has been developed in a conceptual overlap with other tools, and it is unclear yet to what extent the SEWM correlates with measures of actual WM performance. The SEWM scale needs to be further tested in a study on a more comprehensive assessment of WM performance. Additional studies are needed to determine the scale's usefulness and sensitivity for detecting change in perceived self-efficacy as a result of WM interventions for people with SCI during and after rehabilitation.

Conclusions and future applications

SEWM is suggested to be a reliable instrument with a high internal consistency and good concurrent validity for wheelchair dependent athletes with SCI. Comparing and combining the outcomes of the current study with the pilot study results[15], offers a more accurate reflection of WM self-efficacy perceptions among SCI population. It is expected that this scale may find future clinical applications in measuring self-efficacy perceptions in wheelchair skills performance of individuals with SCI, may be a predictor for actual WM performance, and may be used comprehensibly to actual performance-based WM evaluation.

To support the preliminary statistical properties of the SEWM, towards identifying more definitive psychometric characteristics, an extended study, following a test re-test analysis, would be helpful to ascertain the stability of scores. In addition, testing the SEWM with a sedentary population of SCI, and on wheelchair users with different impairments, is highly recommended.

In future studies, it may be useful to reflect on the position of self-efficacy on the outcomes of WM intervention and to test whether self-efficacy is a mediator or moderator for WM skill performance[27]; if perceived self-efficacy in WM is a mediator, it will be responsible for all or part of the effects of a treatment on the outcome (i.e. those with initial higher self-efficacy in wheeled mobility perceptions will perform better). If perceived self-efficacy in WM is a mediator, self-efficacy in WM perceptions will get changed during the intervention, be associated with the treatment, and will have an effect on the outcome.

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Appendix 1: **Self-Efficacy in Wheeled Mobility Scale (SEWM)**

Please tell us **how confident you are with regard to carrying out the wheeled mobility skills below**. (*Please check only one box for each question*)

I am confident that:	***Not at all true***	***Rarely true***	***Moderately true***	***Always true***
I can overcome barriers and challenges regarding wheeled mobility skills if I try hard enough	❑	❑	❑	❑
I can find means and ways to be independently mobile, using my wheelchair in everyday life setting	❑	❑	❑	❑
I can accomplish tasks that require independent wheelchair mobility such as ascending sidewalks and ramps.	❑	❑	❑	❑
When I am confronted with obstacles to wheelchair mobility, I can find solutions to overcome them	❑	❑	❑	❑
I can overcome mobility barriers and challenges even when I am tired	❑	❑	❑	❑
I can be independently mobile with my wheelchair even when I am depressed	❑	❑	❑	❑
I can be mobile with my wheelchair without the support of my family or friends	❑	❑	❑	❑
I can motivate myself to carry out a difficult and challenging wheeled mobility skill	❑	❑	❑	❑
I can learn new skills of wheeled mobility by myself	❑	❑	❑	❑
While using my wheelchair, I can usually handle whatever comes my way	❑	❑	❑	❑

Chapter 6

Most essential wheeled mobility skills for daily life: An international survey among elite athletes with SCI

Fliess-Douer O, Vanlandewijck, YC, van der Woude LH (2012). Most essential wheeled mobility skills for daily life: An international survey among Paralympic wheelchair athletes with SCI. *The Archives of Physical Medicine and Rehabilitation*, 98: 629-635.

Abstract

Objective: To create a hierarchical list of the most essential wheeled mobility (WM) skills for everyday life of wheelchair users with a spinal cord injury (SCI), and to compare perceptions of WM gained during and after clinical rehabilitation.

Design: Cross-sectional study using survey questionnaires.

Setting: During the Beijing Paralympic games, at the international zone of the Olympic village and in different sports venues.

Participants: A sample of men (*n*=49) and women (*n*=30 elite manual wheelchair users' athletes with SCI (paraplegia *n*=64, tetraplegia *n*=15).

Interventions: Not applicable.

Main Outcome Measure: A survey with 24 predefined skills was distributed during the Beijing Paralympic games. Respondents were asked to rate the essentiality of each skill (1, not essential; 5, extremely essential); to state where, when, and with whom they have learned to perform each skill; and to mark the level of WM which they gained during and after clinical rehabilitation, on 3 different WM visual analog scales (scores 0–10).

Result: Rated as the most essential skill was transfer into and out of a car (mean VAS ± SD, 4.7±0.7). Rated as the least essential skill was the 1-handed wheelie (mean VAS ± SD, 1.9±1.3). Of the respondents, 57% have learned the most essential skills in clinical rehabilitation, while 40% claimed to have learned those skills afterward in a community setting. Three percent have never learned to perform the most essential skills. Of the very essential skills, 40% were self-taught. Mean VAS score ± SD for the extent to which WM skills were gained in rehabilitation was 5.4±2.5.

Conclusion: The main survey outcome is a sorted list of WM skills according to their essentiality for daily life of hand-rim wheelchair users with SCI. It is recommended to incorporate the skills that were graded as very essential and extremely essential during inpatient rehabilitation and in post rehabilitation WM workshops.

Keywords: Data collection, Rehabilitation, Spinal cord injuries, Wheelchairs

INTRODUCTION

Manual wheelchair mobility and wheelchair skill competency are important for people with spinal cord injury (SCI), since most of them (approximately 80%) will be reliant on a manually propelled wheelchair for the rest of their life[1]. To function independently, wheelchair users must acquire a variety of wheelchair skills, in order to deal with the physical barriers they will come across in different situations in daily life[2]. Evidently, manual wheelchair skill performance of persons with SCI is positively associated with activities and participation[3].

Wheelchair skill performance is defined as: "The ability to move around and overcome obstacles encountered when carrying out daily activities or social roles in a self-propelled wheelchair"[4]. Wheeled mobility (WM) is defined as: "Moving around using equipment: Moving the whole body from place to place, on any surface or space, by using specific devices designed to facilitate moving or create other ways of moving around, such as moving down the street in a wheelchair or a walker"[5].

WM skills development during clinical rehabilitation should reflect the daily activities and needs of each patient. They should maximize a patient's functional capacity and contribute to reducing an individual's dependency. In order to develop these skills, a standardized assessment tool needs to be developed. A wheeled mobility skills test combines a number of WM tasks that are being performed and assessed under standardized conditions. A validated and reliable WM skills test is necessary as a guiding instrument in the rehabilitation process of manual wheelchair users. Outcomes of such a tool can assist in making the appropriate choice of skills to be trained during and post clinical rehabilitation as well as in the evaluation of training interventions. Furthermore, a standardized and worldwide accepted WM skills test could be used to develop standards of wheelchair skills performance for individuals with different levels of impairment. Although there are different kinds of tests assessing wheelchair skill performance using different tasks and outcome measures [6-11], none of these tests is accepted as a standardized and universal test for the assessment of WM skill performance in all SCI rehabilitation units around the world[12].

In a recently published literature review of existing WM skill tests[13], for most tests, content validity was based on the involvement of health professionals in the development of the test and on literature studies. More precisely, it were health professionals who chose the skills to be included in the WM skill tests, rather than experienced wheelchair users. The literature review recommendation was to choose the skills, for a future developed universal test of WM, based on a large sample of experienced wheelchair users, i.e. by gathering elite wheelchair users' opinions and sorting out the most essential skills for daily life in a wheelchair according to these experts.

The main objective of the current survey was therefore, to create a hierarchical list of the most essential WM skills for everyday life of wheelchair users with SCI. A suggestion that was raised after reviewing the results of a pilot study (SCI, *n*=47, wheelchair basketball players vs. recreational level and non-active participants), was to compare the pilot study survey results, with the opinions of Paralympian wheelchair athletes. The reason for conducting this survey among Paralympian athletes with SCI is the assumption that this population may demonstrate the best wheelchair skill performance, and could be the benchmark to reach in terms of wheelchair skills. Furthermore, if the sorted list of the most essential WM skills formed in this study will be comparable and consistent with the list sorted by the recreational and the non-active group participating in the pilot study, it will allow a careful generalization of both studies' result to the entire population of SCI.

The main research question of this study was: what are the most essential WM skills for daily life of manual wheelchair athletes with SCI? The study hypotheses were: (1) The rating of the 10 most essential skills will be similar to the pilot study rating; (2) The participants in this study will indicate that they have learned to perform the most essential WM skills during the rehabilitation phase by professional instructors; (3) The participants will perceive the level of WM gained and the time dedicated for teaching WM during the clinical rehabilitation phase as moderate (good); (4) WM perceptions at present will be significantly higher compared with those at the time of discharge from the rehabilitation centers; and (5) There will be significant differences in perceived level of WM between individuals with paraplegia and tetraplegia.

METHODS

Survey Development

We created the most essential WM skills for daily life of wheelchair users with SCI survey, and its companion, the open questions form, in the beginning of 2008. During the survey development period, decisions about survey content (skills included in the survey) and design were based on literature on WM skill tests that were published between 1970 and 2007,11 the researchers' own experiences working with individuals with SCI, and the British Spinal Injuries Association Turning the Corner DVD (2003, all rights reserved, available at: http://www.spinal.co.uk/product.php?productID=173&categoryID=23).

The process of survey development was iterative, with repeated reviews and comments by a panel of experts working in the field of SCI, that was composed of 1 professor (physical therapist, a wheelchair basketball ex-player, and a coach with an experience of 30y), 2 PhD students (physical therapist and adapted physical activity specialists), and 2 athletes with a SCI (paraplegia and tetraplegia). The type of survey was chosen to be a unidimensional simple structure (indicating that each item in the survey helps to explain 1 and only 1 particular construct), asking for rating rather than ranking.

After a period of review and revisions, the survey was piloted with a group of purposively selected individuals with SCI, (*n*=47, Lesion level ranged T4–L4), representing different activity levels (recreational and elite athletes), and six different countries (UK, Greece, Israel, The Netherlands, Belgium and USA). Instructions were provided to complete the survey. After answering the survey, the first author questioned the participants and asked for feedback regarding the clarity of the survey content, the ease of completion, the sensitivity of questions, and perceptions of survey length.

The survey was originally developed in English and translated to French, Spanish, Dutch, Chinese and Hebrew by external experts in the field, who speak both languages fluently, following a bi-directional (forward and backward) translation procedure.

Design

This study was conducted in accordance with the guidelines of the Declaration of Helsinki, and was approved and supported by the International Paralympic Committee, Sport Science Committee (IPC SSC).

The participants who declared consent to participate in this study received forms to complete; the cluster of questionnaires included: a consent form, a personal information form (collecting basic information about the medical and sport history of the participants), the most essential WM skills for daily life of wheelchair users with SCI survey, and 3 WM visual analog scales (VASs). The survey included 24 skills, which the participants had to rate according to their essentiality for daily life. The participants were asked to: (1) state the essentiality of each skill (1, not essential; 5, extremely essential), and (2) state where and with whom they have learned to perform each skill.

To ensure that the athletes participated in this study would sort the skills according to the essentiality for all wheelchair users, and not in particular for their own athlete's needs, the opening sentence in the survey was: "The goal of this survey is to collect Spinal Cord Injured persons' opinions regarding the most essential WM for daily life skills. Please rank how essential for a wheelchair user the following every day wheelchair skills are."

The 3 WM VAS scales after the survey included the questions: (1) How would you describe the level of your wheeled mobility skills gained during the rehabilitation period?; (2) How would you describe the amount of time dedicated for training wheeled mobility skills during your inpatient stay at the hospital?; and (3) How would you describe your level of wheeled mobility skills performance today? To assist the respondents (especially the tetraplegic group that might have writing difficulties), the participants were asked to answer these questions by placing a vertical mark (| or X) on a 10-cm line (0–10 VAS, where 0 is equal to poor and 10 is equal to excellent). In this study, it was the first time that a VAS method has been applied on WM perceptions. However, in clinical rehabilitation, the VAS method was used in a few studies, and not only for measuring pain, but also for measuring sense of illness, self-feeling, and more.[14] After marking the 3 WM VAS scales, the participants were asked to voluntarily share any comment concerning the studied topic.

Data collection and sample characteristics

Several approaches were combined in order to increase responses and minimize the interference to the athletes' schedule during the hectic time of the Paralympic games: During the first days of the games, the researchers met all wheelchair basketball and wheelchair rugby team managers (men and women), and briefly explained the study's aims and distributed the questionnaires. It was clarified that only athletes with SCI who are primarily wheelchair dependent can participate in the study. Mobile telephone numbers of the managers were collected for sending reminders by text message (SMS). In addition, the research team handed questionnaires to wheelchair basketball and wheelchair rugby players off court between games. In individual sports, (wheelchair tennis, archery, fencing etc.), the research team handed the questionnaires to SCI athletes while they were watching other matches and during their free time at the international zone in the Paralympic village. Completed questionnaires were returned by team managers or individual participants through a mailbox at the polyclinic in the athletes' Paralympic Village.

Approximately 250 questionnaires were passed to team managers and to individual athletes. Ninety-four questionnaires were returned, but only 79 were sufficiently completed, that is, with all the questions regarding WM skills rated (for the survey analysis, n=79), and at least 2 out of 3 WM VAS scales filled (10 missing data for the VAS analysis, n=69). Of the omitted questionnaires, 3 athletes from China, after completing the questionnaire, asked not to be included in the study; 2 athletes completed the questionnaires but did not have a SCI; 5 participants skipped the personal information form; 2 participants marked all the skills as extremely essential and marked all 3 VAS scores the same (either due to lack of understanding or lack of motivation); 2 participants did not mark when and with whom they initially learned to perform the listed WM skills; and 1 athlete skipped the VAS scales page. Out of these 15 participants, only 1 had a tetraplegia and only 1 was a woman. There was no identified consistency or a link between the people who had filled in the omitted questionnaires.

The study sample includes 49 men and 30 women athletes from 18 countries and 14 sports disciplines. The sample includes 64 individuals with paraplegia and 15 individuals with tetraplegia. Age ranges 14 to 53 years (mean age ±SD, 33±8.18), time since injury varies between 3 and 31 years (mean ± SD, 15.5±6.63), and time participating in Paralympics sport ranges 1 to 22 years (mean ± SD, 10±5.5). Sample characteristics are presented in Table 1.

Table 1: **Sample characteristics**

Characteristics	*n* Paralympic study	*n* Pilot study
Countries, *n*		
Australia	2	NT
Canada	5	NT
Colombia	1	NT
France	8	NT
Great Britain	13	3
Germany	2	NT
Greece	3	4
Hungary	1	NT
Ireland	3	NT
Israel	9	19
Italy	1	NT
Morocco	1	NT
New Zealand	2	NT
Romania	1	NT
Spain	3	NT
Sweden	3	NT
USA	20	3
Zimbabwe	1	NT
The Netherlands	NT	5
Belgium	NT	13
Male, *n*	49	42
Female, *n*	30	5
Age, years, mean (SD) [range]	33 (8.1) [14-53]	38.2 (13.9) [18-75]
Time since injury, mean (SD) [range]	15.5 (6.6) [3-31]	16.9 (13.1) [2-52]
Lesion level		
Paraplegia / Tetraplegia (missing data), [range], *n*	64/15 (3) [C5 – L4]	47/0 [T1 – L3]
Complete/Incomplete SCI (missing data), *n*	46/25 (8)	14/7 (1)

Note. Values are *n* or as otherwise indicated.
NT – Not tested

Statistical procedures

Descriptive statistics and paired sample *t* tests were carried out in accordance with the descriptive nature of the current study. For testing skills essentiality, the skills were sorted according to the average scores; descriptive statistics were used to present the survey results and to compare these with the pilot study results (hypothesis 1 and 2). SE of the means (SD of the error in the sample mean relative to the true mean) and relative SEs were also calculated[15]. Total VAS average scores were used to indicate the perception of WM levels and the amount of time dedicated for teaching WM skills during the acute rehabilitation phase (hypothesis 3). A Student *t* test was used to compare the VAS scores of perceived WM gained during rehabilitation with the VAS scores indicating perceived WM level at present, in order to examine whether WM perceptions changed over time (hypothesis 4). The *t* test was preceded by the Levene test for equality of variance in order to establish the degree of freedom. Cases with missing data in any variable were excluded from the analysis. For testing hypothesis 5, the scores of the VAS scale representing perceived level of WM at present were used to determine the differences between participants' lesion levels (paraplegia vs. tetraplegia), and the differences were tested by a *t* test for equality of means.

RESULTS

Hypothesis 1. The complete list of skills, sorted by essentiality level (main research question), of both the pilot study and the current study, are presented in Table 2. The most essential skills (with an average score > 4.0) were found to be: transferring into a car/out of a car (mean ± SD, 4.7±0.7), wheeling 50 m forward (mean ± SD, 4.4±1.0), and going up a ramp and opening a door (mean ± SD, 4.3±0.9). The less essential skills were: 1 handed wheelie (mean ± SD, 1.9±1.3), going up and down a flight of 5 stairs with a handrail (mean ± SD, 2.3±1.4), and 5 minutes propulsion on a treadmill (mean ± SD, 2.8±1.4). In the current study, SE of the means ranged between 0.08 to 0.18 and the relative SEs ranged between 2% to 8%. In clinical health-related research, it is a common practice to report an estimate of the mean only if the relative SE associated with it is less than 30%[15].

Hypothesis 2. After sorting the list of skills, the skills with an average score above 4.0 were categorized into 2 subgroups: once according to the place where the skill was taught, and second, according to with whom the skill was initially trained. Fifty-seven percent of the respondents stated that they have learned to perform the most essential skills at the early rehabilitation phase, 33% claimed to have learned to perform those skills elsewhere after clinical rehabilitation, 7% of the respondents learned to perform the most essential skills in sport activity after rehabilitation, while 3% have never learned to perform the most essential skills. Of the respondents, 42% stated that they have learned to perform the most essential skills by themselves, 42% learned the most essential skills from a professional instructor, 13% have learned the most essential skills from a peer, and 3% have never learned to perform the most essential skills.

Table 2: **The list of the daily WM skills sorted by level of essentiality (1-5 scale)**

The skill	Paralympic study (*n*=79)	SEM + (%RSE)	Pilot study (*n*=47)	SEM + (%RSE)	Pilot study recreation group (*n*=22)	SEM + (%RSE)
Transferring into a car / out of a car	4.7 ±0.7	0.08 (2)	4.7±0.8	0.12 (3)	4.8±0.7	0.14 (3)
50 meter forward	4.4 ±1.0	0.12 (3)	4.1±1.4	0.16 (4)	4.6±0.8	0.18 (4)
Going up a ramp and opening a door	4.3 ±0.9	0.11 (2)	4.1±1.2	0.19 (4)	4.2±1.1	0.22 (5)
Up and down hill gentle slope (6 meter)	4.3 ±0.8	0.09 (2)	4.0±1.2	0.20 (5)	4.0±1.2	0.24 (6)
Ascending/descending 2.5cm sidewalk	4.2 ±1.1	0.13 (3)	4.2±1.3	0.19 (5)	4.3±1.0	0.23 (6)
Transferring from one wheelchair to another	4.1 ±1.3	0.14 (3)	4.1±1.3	0.17 (4)	4.0±1.3	0.27 (7)
Transferring from the floor to a wheelchair	4.1 ±1.3	0.14 (3)	4.0±1.3	0.17 (4)	**3.8±1.4**	0.25 (6)
Ascending/descending 5cm sidewalk	4.0 ±1.2	0.14 (3)	4.2±1.1	0.20 (5)	4.3±1.1	0.24 (6)
Moving on irregular surface propulsion	4.0 ±1.1	0.12 (3)	**3.9±1.1**	0.20 (5)	**3.9±1.1**	0.29 (8)
Going up & down a steep slope (6 meter)	3.9 ±1.0	0.11 (3)	**4.0±1.2**	0.16 (4)	3.4±1.3	0.30 (8)
Transferring from a wheelchair to the floor	3.9 ±1.3	0.15 (4)	3.9±1.4	0.20 (5)	3.7±1.5	0.31 (8)
Crossing a steep slope	3.8 ±1.0	0.11 (3)	3.5±1.3	0.20 (6)	3.4±1.5	0.30 (9)
Wheelie - Stationary	3.7 ±1.4	0.16 (4)	3.7±1.4	0.18 (5)	3.4±1.6	0.35 (10)
Wheelie – Forward	3.7 ±1.3	0.16 (4)	3.8±1.4	0.22 (6)	3.5±1.7	0.34 (10)
Ascending/descending 15cm sidewalk	3.4 ±1.4	0.16 (5)	3.4±1.4	0.25 (7)	3.3±1.5	0.27 (8)
Small jump with the wheelchair	3.3 ±1.4	0.16 (5)	3.6±1.5	0.19 (6)	3.5±1.4	0.31 (9)
50 meter backwards	3.3 ±1.4	0.17 (5)	3.5±1.5	0.19 (5)	3.7±1.4	0.32 (10)
Turn while wheelie	3.0 ±1.5	0.16 (5)	3.4±1.3	0.20 (6)	3.0±1.4	0.30 (10)
Going up and down escalators	3.0 ±1.5	0.17 (6)	**2.6±1.7**	0.24 (8)	**2.1±1.4**	0.36 (13)
20 meter sprint	2.9 ±1.3	0.15 (5)	2.7±1.4	0.24 (9)	2.8±1.6	0.34 (12)
Wheelie – backward	2.8 ±1.6	0.18 (6)	2.1±1.5	0.21 (8)	2.7±1.6	0.34 (13)
5 minutes on a treadmill	2.8 ±1.4	0.17 (6)	2.8±1.6	0.24 (9)	2.8±1.6	0.31 (15)
Going up & down 5 stairs - with handrail	2.3 ±1.4	0.16 (7)	2.3±1.5	0.23 (10)	1.8±1.4	0.29 (16)
One handed wheelie (while holding a cup)	1.9 ±1.3	0.15 (8)	2.1±1.5	0.22 (10)	1.8±1.4	0.30 (17)

NOTE. Values are mean ± SD or as otherwise indicated
Mean symbolized as $\overline{X}$
SEM: $\sigma_{\overline{X}} = \frac{S}{\sqrt{n}}$
% RSE: $\frac{SEM}{\overline{X}}$*100
Abbreviations: %RSE, relative SEs in percentages; SEM, SE of the mean.
Bold numbers: scores that were graded as less/more essential in the pilot study compared to the Paralympic study

Hypothesis 3. Total WM VAS average score of WM ± SD gained during the acute rehabilitation was 5.4±2.5 and total WM VAS average score ± SD of the amount of time dedicated for teaching WM skills during rehabilitation was 5.4±3.1. A graph of the results is presented in figure 1.

Hypothesis 4. Total WM VAS average ± SD of perceived level of WM at present was 8.5±1.5. Only 69 out of 79 participants marked both WM VAS scales and were included in the comparison analysis between perceived WM level at the end of rehabilitation and perceived WM level at present; WM at present was significantly higher than WM gained during rehabilitation (Table 3). Out of 69 cases, 60 participants indicated that their current level of WM is higher than the level attained at the end of the clinical rehabilitation period, 4 participants claimed to have the same WM level today as at the end of rehabilitation, and only 5 stated that their level of WM at the end of the rehabilitation period was higher than today.

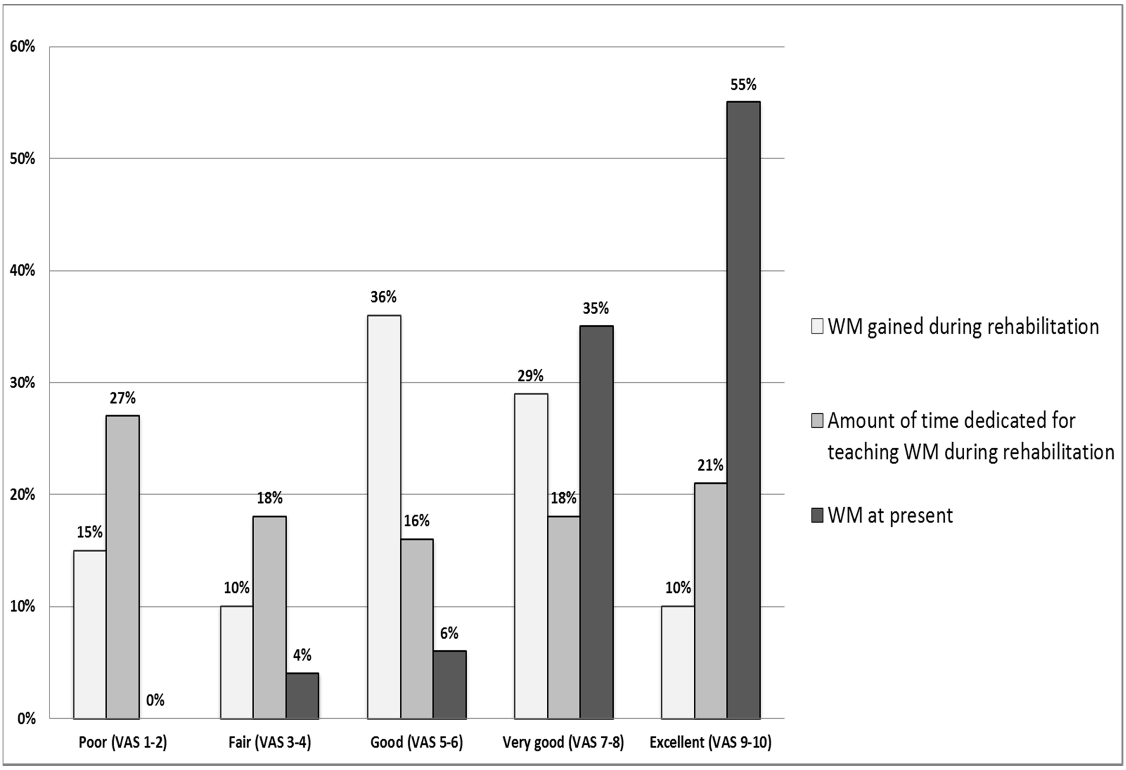

Figure 1: **Perceived level of WM gained during rehabilitation, amount of time dedicated for teaching WM skills during rehabilitation phase and WM at present in percentages** (based on 3 visual analog scales VAS, scored 0-10)

Hypothesis 5. A comparison of the perceived level of WM at present according to different participants' lesion levels indicated, with statistical significance, that individuals with tetraplegia perceived lower WM abilities compared to individuals with paraplegia (Table 3).

Table 3: **Perceived WM level at present compared to at the end of rehabilitation, and perceived WM level at present between participants with different lesion levels (paired sample statistics)**

Variable	VAS Mean (SD) [SEM]	Sig. (2-tailed) [Paired mean difference]
WM levels:		
WM level gained during rehab (*n*=69)	5.41 (2.55) [0.31]	< 0.000001 [-3.1]
WM level at present (*n*=69)	8.54 (1.53) [0.18]	
Lesion comparison:		
WM level at present - Tetraplegia (*n*=15)	7.2 (1.8) [0.47]	0.002 [-1.82]
WM level at present - Paraplegia (*n*=60)	9.05 (1.18) [0.15]	

Abbreviations: WM, Wheeled Mobility; VAS, Visual analog scale; SEM, Standard error of the mean; Sig. Significant

DISCUSSION

The primary goal of the current study was to identify the most essential WM skills for daily life of people with SCI, in order to develop a universal WM test that is relevant and related to daily needs of wheelchair users. The skills that were incorporated in this study were selected from existing WM teaching tools and from published, valid, and reliable wheelchair skill tests, aiming at the general population of SCI and not explicitly meant for athletes. Because the current study sample included only elite athletes and therefore may not be representative for the entire SCI population, a better representation of the SCI population may be achieved by combining the current study results with the pilot study results, which includes a more diverse sample. Therefore, in the discussion, both study results are compared.

Hypothesis 1

As shown in Table 2, the skills that were graded as very and extremely essential were the same in the pilot study and the current study list, except for transferring from the floor to a wheelchair and moving on irregular surface propulsion, that were graded only as essential in the pilot study. The fact the most essential skills were graded the same in both samples strengthen the outcome of the survey. As revealed by the literature review[13], skills that were included in the WM skills tests were often selected by health professionals. The current survey, along with the pilot study results, offers a newly sorted list of skills, based on opinions of an international group of wheelchair users with SCI, representing different levels of activities. From clinical perspectives it means that the survey findings may apply in adults with SCI that are primary wheelchair users and participate in different levels of activities. However, it is not clear whether all these skills can be acquired to maximal proficiency during the acute rehabilitation phase of individuals with SCI. It is advised to use this checklist in post-rehabilitation WM workshops, in case these skills were not achieved during the clinical rehabilitation phase.

Similar to the pilot study results, transferring into a car/out of a car was rated as the most essential skill. A recent literature review of 11 WM measurement tools[13] revealed that this skill was rarely tested, and it was only mentioned in 1 WM skills test published in 1970[10]. The reason for not including transfers into and out of a car in previous WM skills tests could be due to the complexity in standardizing such a task (e.g., having the same car in all tests trials, the same height of the driver seat, the same distance from the sidewalk). In addition, most of the existing WM skills tests were conducted in laboratory settings (rehabilitation centers), while such a skill requires an outdoor examination.

Another illustration of a discrepancy between what is being tested in existing WM skills tests and the skills that are essential for daily life situations is the level propulsion backward. In the current study, as in the pilot study, propelling backward was not rated as very essential; however, it was frequently tested in WM skills tests[6,8,10,11] as reported in the professional literature[13].

The skill going up and down escalators was ranked as essential in the Paralympic study, while in the pilot study it was considered as quite essential only. This could be due to the traveling of Paralympians, and may illustrate some degree of biased opinion if only an elite athlete sample is considered.

Hypothesis 2

Regarding the questions of where, when, and with whom did athletes with SCI learn the most essential WM skills, findings indicate that nearly half of the respondents have learned to perform the most essential WM skills only after discharge from the hospital/rehabilitation centers. In the pilot study, even fewer participants (48% of the respondents) had learned to perform the most essential skills at the hospital, 4% of the respondents learned to perform the most essential skills in sport activity, while 9% had never learned to perform the most essential skills.

The fact that nearly half of the participants did not learn important skills, such as transferring from 1 wheelchair to another (eg, transitioning from the daily wheelchair to the toilet or bath wheelchair or ascending/descending 2.5-cm sidewalk) during the acute rehabilitation phase, is peculiar.

The mean length of stay in clinical rehabilitation reported in the literature shows wide ranges, approximately between 60 and 180 days[16,17]. The ability to cover all areas affected by SCI in 2 months is very difficult, and it could be the reason for the absence of essential WM skills learning, as stated is this study. In addition, due to a lack of scientific reports containing evidence to support all clinical decisions taken during rehabilitation, it may be that different rehabilitation centers implement different procedures and different decisions about the rehabilitation process and therefore it appears to be a difficult task to obtain a detailed description of global pathways for rehabilitation after SCI.

A comprehensive international comparative study on health care policies in neurologic rehabilitation[18] for the post-acute phase indicated that no specific pattern was followed. All of the pathways included physical and occupational therapy and discharge planning from the beginning, though only 1 pathway described intensity of the therapy during the post-acute phase. The content of therapy was not specified. The use of an outcome measurement tool made by the interdisciplinary rehabilitation team itself was once mentioned. One study mentioned the use of the FIM as an outcome tool. No further standardized tools were included for evaluation[18]. This shows that a systematic, worldwide-accepted framework for incorporating WM skills development into the rehabilitation process does not exist. The sorted list of skills presented in this study may assist health professionals in choosing the most essential WM skills to be taught and trained during the rehabilitation phase of people with SCI.

In the pilot study, only 3% of the participants stated that they have learned to perform the most essential skills from peers. In the current study, only 13% claimed to learn WM skills from peers during the inpatient phase. It might indicate that peer learning in the domain of WM is far from gaining its full potential. Salutary lessons can be learned from a study by Hammell[19], who interviewed people with SCI living in their own homes in England. Concern was frequently expressed that the therapists in the spinal cord rehabilitation units had no knowledge or awareness of what it really means to live with a disability in the community. Frustration was directed at "a generic rehabilitation process that aims to teach certain predetermined skills and is out of context with the specific and unique environment of the client, his values or lifestyle." It has been suggested that people learn best from others who are in a similar situation. Carpenter[20], found that newly injured patients compared themselves with more experienced peers. Carpenter also found that opportunities for peer modeling were restricted by the fact that expert peers rarely were in a position to act as such, because "there was no purpose, or inclination, for them to return to the rehabilitation setting." Other studies have reported positive findings regarding peer learning in the rehabilitation context[21,22]. The conclusions were: experienced peers are thought to represent a meaningful contribution to rehabilitation in terms of providing more efficient learning situations. There is also a realization that the professional knowledge of rehabilitation staff is not sufficient for providing a complete rehabilitation service. The lived experiences of others who have gone through rehabilitation processes must be included, also within institutional contexts[23].

Hypothesis 3 and 4

In this study, as in the pilot study, the participants declared that they gained a moderate level of WM during clinical rehabilitation. Also, a clear improvement in WM perceptions over time was demonstrated in both studies. This supports a fundamental assertion of the researchers that WM skills gained during the acute rehabilitation process are not optimal compared with the WM skills of long-term and well-trained wheelchair users with SCI. However, there is a potential for recall bias due to the retrospective nature of this study and the consequent high time since injury.

Hypothesis 5

The significant differences in WM perceptions, between individuals with paraplegia and with tetraplegia, support the results of other studies on SCI, which focus on different functional variables. A cautious conclusion from this finding could be that when teaching and testing WM skills, adaptation for the 2 subgroups (people with tetraplegia and paraplegia) is recommended in order to enhance learning efficiency and tests' responsiveness. However, the subgroup differences in this study were tested with a simple VAS method; it is uncertain whether VAS is an optimal means to expose such information. Using a standardized valid and reliable questionnaire might lead to more accurate results. Yet, in as hectic a time as the Paralympic games, VAS has ultimate advantages. It is a very useful tool for fast scoring, especially for people with tetraplegia with limited hand function, for whom marking a line is much easier than writing or circling. Furthermore, after filling in 3 forms, instead of completing open questions forms, the VAS method assisted and motivated the participants to complete the entire set of questionnaires.

Study limitations

The sample size of both, the current study and the pilot study was n=126, with a majority of active individuals with SCI. In order to achieve supplementary representative results, a randomly selected cross-sectional survey of the larger spinal cord injured population is recommended.

The low return rate of 33% completed questionnaires is also a weakness of this study and it could be due to several reasons: during the Paralympic games, athletes are focused on the most important sports event of their life. It is therefore logical that filling out questionnaires will not be their highest priority. Second, during the Beijing games there were several other studies that were conducted in parallel, which also included questionnaires and targeted the SCI population. Finally, the access of the research team to the Paralympic village (the accommodation area), or to the dressing rooms area at the sports venues, was limited.

The strength of this survey is that it gathered opinions of people from 18 different countries and 5 continents. However, we cannot state conclusions regarding rehabilitation efficiency in different countries (ie, the amount of time dedicated for teaching WM skills at the rehabilitation centers) because the number of representatives from each country is limited and varied and it is a retrospective study based on participants' perceptions and memories.

Conclusion and future recommendations

This survey exposes and rates the most essentials skills for daily life of hand-rim wheelchair users with SCI. It is recommended to incorporate the skills that were graded as very essential and extremely essential during inpatient rehabilitation and in post-rehabilitation WM workshops. The list of skills presented here could be the base for establishing a concrete and, if possible, a global pathway for enhancing, teaching, and assessing WM skills development during clinical rehabilitation of persons with a SCI. Comparing WM teaching methods in different SCI units around the world may offer additional information for this sake. Future studies should also focus on the peer learning process and its potential to promote WM skills learning in this population. In addition, it would be suitable to investigate the broader SCI population and discuss the essential wheelchair skills required by various subsets (eg, employed, full-time parent, older), which may then further the quest to develop an appropriate standardized WM assessment tool.

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Chapter 7

Development of the Test of Wheeled Mobility (TOWM) and a short Wheelie test: A feasibility and validity study of two new tests assessing wheeled mobility skills in persons with spinal cord Injuries

Fliess-Douer O, van der Woude LH, Vanlandewijck, YC. (2012). Development of the Test of Wheeled Mobility (TOWM) and a short Wheelie test: A feasibility and validity study of two new tests assessing wheeled mobility skills in persons with spinal cord injuries. *Clinical Rehabilitation*, Submitted for publication.

ABSTRACT

Objective: To assess the feasibility and validity of both, the Test of Wheeled mobility (TOWM) and the Wheelie test.

Design: Cross-sectional study.

Setting: KU Leuven gymnasium.

Subjects: 30 male manual wheelchair users (Age range 23-53y) with spinal cord injury (Lesion level range C5 – L1).

Interventions: Participants preformed both tests after completing a personal information form and a 'Perceived self-efficacy in WM' scale. The TOWM consists of 30 tasks reflecting functional wheeled mobility. The Wheelie test consists of 8 tasks measuring the ability to perform a wheelie in challenging situations[1].

Main measure: Ability scores, time scores, qualitative scores, and anxiety scores were assessed. Convergent validity was tested by correlating the TOWM and the Wheelie test scores. Construct validity was assessed by testing whether the four scores of both tests are significantly related to perceived self-efficacy in wheeled mobility, time since injury, and sport participation.

Results: TOWM average total testing time was 24.7 min. (±5.93) and the Wheelie test was 12.62 min. (±5.08). Concurrent validity was confirmed by the positive correlation between the TOWM and Wheelie test total ability scores (r=0.84; p<0.001), quality scores (r=0.88), and anxiety VAS scores (r=0.66). Moderate correlation were found between the total time scores of the TOWM and Wheelie test (r=0.47). Construct validity was confirmed by fair to moderate correlations between both test's scores with time since injury, self-efficacy, and sport participation after injury.

Conclusion: The TOWM and the Wheelie tests are feasible and valid instruments for assessing manual wheelchair mobility in persons with SCI.

Keywords: Wheeled mobility, Spinal cord injury, Evaluation, Validity, Wheelie, Wheelchair skill

[1] The test protocol can be freely obtained from: www.scionn.nl/inhoudp28.htm

INTRODUCTION

In many situations, wheeled mobility is necessary to facilitate access to social, professional and recreational activities. When mobility is limited because of a spinal cord injury, a wheelchair provides an effective means for mobility and often it is the only alternative to walking.

According to the International Classification of Functioning Disability and Health (ICF), the concept of wheeled mobility is a subcategory of "Moving around using equipment: moving the whole body from place to place, on any surface or space, by using specific devices, designed to facilitate moving or create other ways of moving around, such as moving down the street in a wheelchair or a walker"[1].

In a recent systematic literature review on wheelchair skill tests[2], results showed that only few tests focus explicitly on wheeled mobility in persons with a spinal cord injury [3-6]. Wheelchair skill tests that were aiming to the general wheelchair user's populations failed to differentiate between levels of performance and resulted in a "ceiling effect", mainly in individuals with paraplegia[2]. The review study revealed a lack of a broadly accepted wheelchair skills test, and disclosed large inconsistencies among the current available tests, which made comparison of study results difficult if not impossible[2]. Furthermore, constituting a standardized and worldwide accepted wheeled mobility skills test will enable to create norms and standards for wheelchair skills performance of individuals with different spinal cord injuries.

This study aimed to develop two wheeled mobility skill tests for manual wheelchair users with a spinal cord injury: one is the 'Test of Wheeled Mobility' (TOWM) which is a comprehensive test based on daily wheeled mobility skills; and the second is a short Wheelie test, aimed for fast and easy screening, developed following the realization that: "The ability to master a wheelie (balancing on the rear wheels), is perhaps the most important skill for the wheelchair user as wheelies permit access to areas and environments that would otherwise be inaccessible"[7].

The aim of this study was therefore to asses both tests' feasibility, concurrent, construct, and predictive validity, and when possible, to compare one test with the other. The main research questions were: (1) Will the tests be feasible in terms of duration and required equipment costs? (2) Will the scores of the

TOWM be significantly correlated with the scores of the Wheelie test? (Convergent validity), and will the Wheelie test scores predict the TOWM scores? (Predictive validity) (3) Will the TOWM and the Wheelie test scores be associated with the variables: 'time since injury', 'perceived self-efficacy in wheeled mobility' and 'participating in sport after injury'? (Construct validity)

METHODS

The development process of the TOWM and the Wheelie test

The research team developed the tests included seven researchers with both, theoretical and clinical experience in spinal cord injuries rehabilitation. In order to promote a standardized wheeled mobility test, the TOWM includes dominant components from existing wheeled mobility tests as found in Fliess-Douer et al. critical literature review[2]. Skill's selection was based on the result of an international survey on wheeled mobility skill's essentiality that was conducted during the Beijing Paralympics games 2008[8]. The set of skills were linked to the UN-norms, standards and architectural accessibility codes[9], to associate the skills with international environmental settings for wheelchair users. After completing the first test draft, a brainstorm-session of experts was organized to increase the tests' content validity. Eight manual wheelchair users with a spinal cord injury (prototype representatives per lesion level) were voluntarily participated in this "experts group". A tryout was carried out following discussions and the participants were questioned whether they felt safe and whether they experienced the tasks to be either too difficult or too easy. The description of the TOWM and the Wheelie test tasks is presented in Appendix 1 and the score sheets are presented in Appendix 2.

Outcome Measures:

The final version of the TOWM consists of 30 standardized tasks which are conditional to mobility in persons with a spinal cord injury. The short Wheelie test includes eight tasks which are related to the ability to perform a mature wheelie in challenging situations. The TOWM and the Wheelie test tasks present different difficulty levels and are hierarchically structured from the easiest to the most difficult. Including preparation and evaluation time, the estimated duration of the tests is 40 minutes[10]. Figure 1 illustrates a few examples of the TOWM and the Wheelie test tasks. The TOWM and Wheelie test protocols, including the score sheets and detailed explanation may be freely obtained at: www.scionn.nl/inhoudp28.htm.

Both tests have the same four scoring methods: The *ability score* refers to all the tasks that can be performed adequately and independently. Scores are being assigned as: 1 point if the participant completes the task successfully in the first trial, and 0.5 point if he succeeds on the second trial. 0 score presents either a failure or avoiding trying. All scores are summed to give an overall ability score (TOWM min = 0, max = 30, Wheelie test min = 0, max =8). The ability score is easy to calculate and to evaluate on the spot, and provides information about the ability of participants to perform the various test items.

The *quality score* reflects the maturity pattern of skill performance. For ten skills of the TOWM and for all eight skills of the wheelie test, there are five behavioral components, which are presented as "performance criteria". The establishment of these criteria was done by two experts, with a great amount of knowledge about the theoretical background of spinal cord injuries. This scoring method offers a meaningful feedback regarding how well one performs each wheeled mobility task, and the maturity level of the overall wheeled mobility performance. All scores are summed to give an overall quality score (TOWM min = 0, max = 50, Wheelie test min = 0 max = 40). Depending on the numbers of examiners, the quality score can be assessed on field, but may be also assessed afterwards by analyzing videos.

The *performance time score* is the sum of the performance times of 2 tasks of the TOWM (Level propulsion forward and one-hand propulsion on a marked 10m line), and 4 tasks of the Wheelie test (Forward 10m in a wheelie, backward 10m in a wheelie, uneven surface and accelerate and stop in a wheelie).

The *anxiety score* is tested by using a visual-analogue scale (VAS 0-10)[8]. Prior to each task performance, the participant is asked to indicate, by placing a vertical mark | or X on a 10 cm line, how anxious he is regarding performing the specific task. This scoring technique is being added to observe the effect of the psychological variable (anxiety) on the execution of each task. A total anxiety score is the sum of all the anxiety visual-analogue scale scores.

Sample characteristics

Recruitment was done during the first two weeks of February 2011, and was performed by word of mouth, email and telephone calls. Communications targeted the heads of a spinal cord injury rehabilitation units and managers of organizations and sport clubs in Belgium. *Inclusion criteria:* Participants were eligible to join the study if they had an acute spinal cord injury, were between 18 and 65 years; categorized as A, B, C or D on the American Spinal Injury Association impairment scale (ASIA)[11]; wheelchair dependent manual wheelchair users; without progressive diseases or psychiatric disorders and who have sufficient knowledge of the Dutch and/or English language to understand the goal of the study and the testing methods. *Exclusion Criteria*: Participants who were not allowed to perform physical tests, and/or had severe musculoskeletal complaints of the upper extremities, neck or back.

Participants

Thirty participants completed the entire set of questionnaires and preformed the TOWM and the Wheelie test at test occasion 1 (t1). One participant did not participate in the retest (t2) due to a recurrence of an old shoulder injury unrelated to the wheeled mobility testing; therefore, the results of 29 participants were included in the presented data analysis. Spinal cord injury lesion level ranged from C5 – L1, (tetraplegic n=6, high paraplegic n=16, low paraplegic n=7). The descriptive group statistics as well as the TOWM, the Wheelie test scores and the perceived self-efficacy in wheeled mobility scale scores are presented in Table 1.

Table 1: **Descriptive group statistics and mean scores of perceived self-efficacy in wheeled mobility (SEWM), TOWM (Test of Wheeled Mobility), and Wheelie test at t1 (*n*=29)**

Variable	***n***	**Mean + SD**
Age, years, mean (SD) [range]	29	38.8 (±8.0) [23-53]
Time since injury, years, mean (SD) [range]	29	12.4 (±10.5) [1-35]
BMI (kg/m^2) ,mean (SD) [range]	29	24.2 (±3.9) [16.5-32.2]
SEWM scale 0-40, mean (SD) [range]	29	34.5 (±4.2) [22-40]
TOWM ability score *scale 0-30*, mean (SD) [range]	29	20.6 (±4.5) [11.5-28.0]
TOWM time score *in sec*. mean (SD) [range]	15	17.6 (±8.3) [10.9-41]
TOWM quality score *scale 0-50*, mean (SD) [range]	20	28.8 (±13.5) [7-48]
TOWM anxiety score *VAS 0-10 X 30 items*, mean (SD) [range]	29	14.6 (±21.5) [0-66]
Wheelie test ability score *scale 0-8*, mean (SD) [range]	29	5.2 (±2.3) [0-8]
Wheelie test time score *in sec*. mean (SD) [range]	15	13.2 (±5.5) [6.6-23.6]
Wheelie test quality score scale 0-40, mean (SD) [range]	20	17 (±11.9) [0-35]
Wheelie test anxiety score (VAS 0-10 X 8 items) , mean (SD) [range]	29	6.2 (±10.7) [0-32]

BMI - Body mass index; SEWM – Self-efficacy in wheeled mobility; VAS – visual analog scale

Testing procedure

The test procedures were performed in accordance with the guidelines of the Helsinki Declaration. The study was approved by the Medical Ethics Committee of the KU Leuven, Belgium. Participation was strictly voluntary and participants signed a consent form. Participants were reimbursed for transportation costs.

Following an explanation about the study aims and procedures, the participants completed a personal information form, including information about sport participation at present, and a 'Perceived self-efficacy in wheeled mobility' scale[12-13]. Body dimensions were measured by deriving the body mass index (BMI=weight (kg) × height $^{-2}$(m)) from the participant's weight and height.

Both tests (TOWM followed by the Wheelie test) were performed while the participants were using their own daily wheelchair. Participants were instructed to perform each task as fast as possible while keeping continuous control over their wheelchair. Participants were given only one trial for each task, and were told that it is more important to execute each task safe and in a controlled way than doing it fast; if they failed, they could try once again (maximum two trials per task).

To further standardize the testing protocol, the same safety precautions were taken for all the participants. Participants were asked to refrain from smoking, drinking alcohol and caffeine products for at least two hours before each trial, all tests were videotaped by the same cameraman using the same high speed camera (Canon, Basler 100Hz, Canon Inc., Tokyo, Japan) placed on a marked line, and and all the instructions were standardized and given by the same researcher who also completed the score sheet.

Statistical procedures and analysis

Descriptive statistic and validity analysis were performed using SPSS (version 16.0, SPSS Inc., Chicago, USA). In this study, ability scores and anxiety scores were available for all 29 participants. Quality scores assessment was performed after the test by experienced physiotherapist, based on a random selection of 20 participants' videos. Only tasks that had an ability score (i.e. the participant successfully completed the task) were qualitatively evaluated. Time score analysis was done based on participants who had a complete set for both tests' time scores (two tasks of the TOWM and four tasks of the Wheelie test) (n=15).

Pearson correlation coefficients were calculated for testing the correlation between the TOWM and the Wheelie test total ability, time and quality scores, and Spearman's nonparametric correlation analysis was used to determine the correlations between both test's anxiety scores (convergent validity). Regression analysis for testing the ability of the wheelie test to predict the TOWM was also performed (Predictive validity).

To determine the relations between the TOWM and the Wheelie test total scores with 'time since injury', Pearson correlation coefficients were calculated; to determine the correlations between both tests scores and the 'perceived self-efficacy in wheeled mobility scale' scores, Spearman's nonparametric correlation analysis was used (construct validity). As suggested by Colton[14], correlations ranging from 0.00 to 0.25 indicate little or no relationship; those from 0.25 to 0.50 suggest a fair degree of relationship; values of 0.50 to 0.75 are moderate to good; and values above 0.75 are considered good to excellent.

For testing association between the TOWM and the Wheelie test total scores and 'participation in sports after injury', a *t* test for equality of means was used. The Participants were divided into two groups: participating in *any type of sport* (n=18; being a member of an official sports club and had at least two years of involvement), and *none* (n=11; no member of an official sports club or less than two years of experience).

RESULTS

Feasibility (research question 1). The average total testing time for the TOWM was 24.7 minutes (±5.93) and ranged between 18-40 minutes. For the Wheelie test, the average total testing time was 12.6 minutes (±5.08) and the range was 4-27 minutes. This total time includes instructions and test's performance. All the participants were able to perform at least 11 out of the 30 tasks of the TOWM. Of the Wheelie test, except for one participant (C5 tetraplegia) all the participant had an ability score of at least one task, but the majority (including the one who scored zero) made an attempt to perform at least the first two tasks. Figure 2 and 3 show for each participant, the Wheelie test ability and quality scores relative to the TOWM ability and quality scores. The graph demonstrates two main outcomes: first, it shows the spreading of scores over the full range of the scale among participants. Secondly, it illustrates the coherence of the two tests to one another as all points are relatively close to the line of identity.

Correlation between the TOWM and the Wheelie test (convergent validity research question 2). The correlation between the total scores of the TOWM and Wheelie test was positive and high (ability score r=0.84; p<0.001, quality score r=0.88; p<0.001, anxiety score r=0.81; p<0.001), except for the moderate correlation between the total time scores of the TOWM and the Wheelie test (r=0.47; p=0.08).

Wheelie test as a predictor for the TOWM (Predictive validity). A linear regression analysis resulted in a high explained variance of 71.3% for the ability scores, and an even higher explained variance of 78.7% for the quality scores. The regression analysis of the anxiety scores provided explained variance of 66%. However, for the time scores, a linear regression analysis resulted with explained variance of only 22.3%.

Association between the TOWM and the Wheelie test scores with wheeled mobility related variables (Construct validity – research question 3). Correlations between the TOWM and the Wheelie test ability, quality and anxiety scores and 'perceived self-efficacy in wheeled mobility scale' total scores varied from fair to moderate (Table 2). No correlation was found between TOWM total time score and the 'perceived self-efficacy in wheeled mobility scale' total score (r=-0.20). Both correlations of the tests' total anxiety scores with 'perceived self-efficacy in wheeled mobility scale' were negative, meaning that lower values of anxiety go with higher self-efficacy in wheeled mobility perceptions.

Both tests' total scores, of all four scales, showed fair to moderate correlations with 'time since injury'. However, the highest values were found between both tests quality scores with 'time since injury' (TOWM r=0.45, Wheelie test r=0.57) (Table 2).

Associations between wheeled mobility and 'participating in sport after injury': ability and quality scores showed significant differences between the active and the none-active individuals in both tests. Those who were not active in sport, scored on an average 19 points less on the TOWM, and 17 points less on the wheelie test, compared to the active participants. Since the none-active in sport participants did not complete all six time scores' tasks, time score comparison between the active and none-active group could not be performed. No significant differences were found between the two groups based on the anxiety scores.

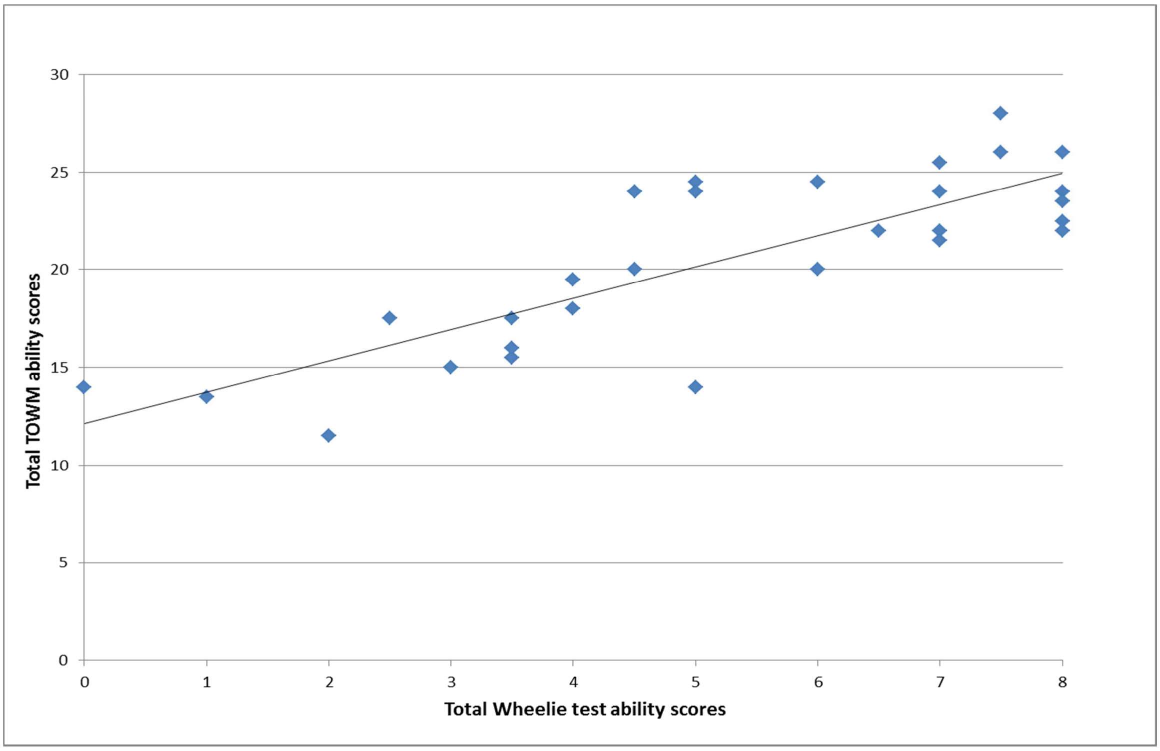

Figure 1: **Scatter gram of the Wheelie test ability scores relative to the TOWM ability scores, per participant (*n*=29)**

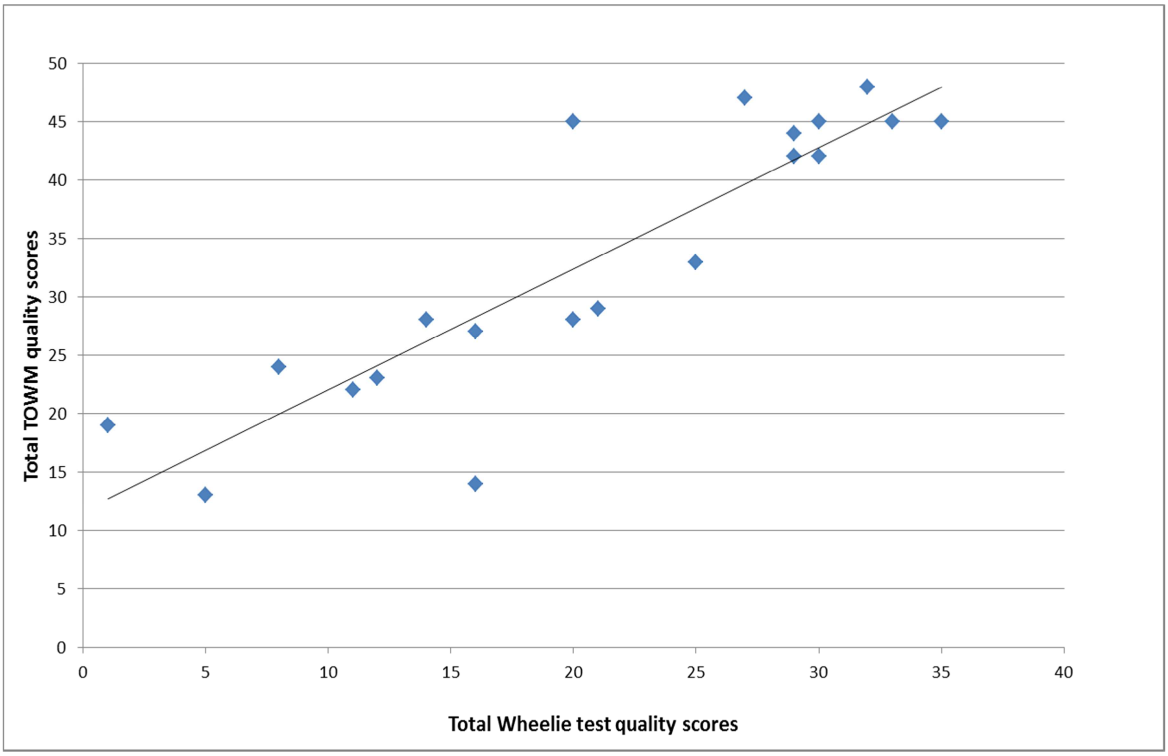

Figure 2: **Scatter gram of the Wheelie test quality scores relative to the TOWM quality scores, per participant (*n*=20)**

Table 2: **Pearson's and Spearman's coefficient of correlation showing the relationship of the TOWM and the Wheelie test scores with wheelchair-mobility related variables**

Variable Test and scale	Time since injury (y) Corr. (Sig.)	SEWM Corr. (Sig.)	Sport participation after injury Sig. (Mean diff)**
TOWM ability scores	0.31* (0.09)	0.36* (0.05)	0.001 (-5.3)
TOWM quality scores	0.45* (0.04)	0.42* (0.06)	<0.001 (-18.9)
TOWM time scores	-0.34* (0.22)	-0.12 (0.67)	NA
TOWM anxiety scores	0.02 (0.92)	-0.56* (0.003)	0.26 (13.4)
WT ability scores	0.42* (0.02)	0.37* (0.04)	<0.001(-3.5)
WT quality scores	0.57* (0.007)	0.37* (0.11)	.0001 (-17.4)
WT time scores	-0.28 (0.30)	-0.21 (0.45)	NA
WT anxiety scores	0.009 (0.96)	-0.50* (0.01)	0.31 (3.04)

Corr: Correlation (Pearson/Spearman); Sig: significant (based on a *t*-test for equality of means, 2-tailed); WT: Wheelie test; NA: not applicable
** Mean diff: mean difference (between athletes to none-athletes)
* Fair and above degree of relationship

DISCUSSION

Main findings supported the feasibility of both tests (in terms of duration and costs). Concurrent validity was confirmed by the positive correlation between the TOWM and Wheelie test total ability, quality and anxiety scores. Construct validity was confirmed by fair to moderate correlations between both test's scores with time since injury, self-efficacy, and sport participation after injury.

To maximize *Content validity,* the test protocol was based on the set of skills derived from a critical literature review[2] and on the sorted list of wheeled mobility skills established following a large international survey among wheelchair users[8]. In addition, a variety of professionals were consulted during the development process, including physical therapists, movement scientists and wheelchair sports trainers, as well as experienced wheelchair users with a spinal cord injury, varied in lesion level.

Feasibility and complexity. The *duration* of a test is a consequence of the number and complexity of the skills included in the test[2]. The TOWM's 30 tasks were tested on average time of 24.7 minutes which is reasonable and shorter than other existing wheeled mobility skill tests (i.e. the VFM[5] test assessed 61 skills within 30-50 minutes, the WST 2.4[15] assessed 50 skills within 27 minutes, and the WUFA[16] test assessed 13 skills in 1 – 1.5 hours). Based on the reported test times in Fliess-Douer's et al. literature review[2], the Wheelie test developed in this study is the shortest wheeled mobility test.

A preference was made for *equipment* that is already available in most rehabilitation centers and training facilities. This proved to be impossible for all the equipment necessary for the tests, so a choice was made to include materials that were limited in both, cost and space requirements. Some of this equipment, such as the portable wheelchair ramp, can also be used for wheelchair skills training, which make it easier for rehabilitation centers to justify the purchase. For the Wheelie test, less expensive and simpler equipment was required.

Generally, the skills were found to be *safe*, but there could be a risk of tipping backwards in certain tasks. Safety precautions should always be taken and several safety notes were therefore added to the test protocol following this study.

The *type of wheelchair* has an important impact on carrying out a task, especially when testing level of performance. Aiming the wheeled mobility test for daily activities, the use of the participants' own wheelchair was chosen and it probably reflects better the participant's wheeled mobility performance levels.

Accessibility to the test protocols is important in order to understand the instructions and settings of the tasks. This may also invite rehabilitation professionals and other researchers to use the same test, and may promote the use of a universal test of wheeled mobility (www.scionn.nl/inhoudp28.htm).

Scaling and outcome parameters. Assessing the ability scores was easy, required minimal training and the results were easy to interpret and compare. These scores alone already enable to differentiate between people's wheeled mobility abilities; however, 5 particpants (all with paraplegia, top athletes) had reached the maximum ability score on the wheelie test, indicates a ceiling effect. Evaluating qualitatively the maturity pattern of wheeled mobility skill performance, based on selected "performance criteria", is a unique method that was developed in the current study and is different from all other existing scoring systems presented in previous wheelchair skill tests. This scoring method offers a meaningful feedback both, to the participant and the therapist, about the mistake made and how to correct in next trials.

In general, the ability scores of the TOWM ranged from 11.5-28.0 and thus did not cover the entire possible score range. The absence of lower scores might be due to the fact that all the participants already received a minimum amount of wheelchair skills training as they were already discharged from rehabilitation for at least two months. When other populations would be tested, (e.g. spinal cord injured patients in early rehabilitation or elderly people), the results might be different. It is important to state that there was no task which all the participants could not perform.

The fact that only the active participants in the current study achieved all possible six time scores should be noted. It is questionable whether time scores are relevant at all when measuring skill performance. Time is a measure that can be used to clearly document the progress of an individual when repeated measures are taken[17]. But from a rehabilitation perspective, therapists certainly want to improve the ability and quality of wheeled mobility performance rather than the time taken for executing a skill. Routhier et al[18] stated that one should be careful with the use of time in short tasks (e.g. getting over 2cm threshold). If a wheelchair user takes 15 seconds instead of 10 (an extra 50%) to achieve a task, it does not necessarily mean that the wheelchair user has difficulties.

The high correlation found between the TOWM and Wheelie test ability, quality and anxiety scores (*convergent validity*) indicated that the ability to master a wheelie was related to the functional tasks of the TOWM. Although the results highlighted the importance of wheelie skills, further research is necessary in order to determine whether training wheelie skills will also result in a better performance on the functional tasks of the TOWM. The Wheelie test was easy to test and much shorter than the TOWM. It allowed a prompt insight of someone's maturity in wheeled mobility performance; it challenged the participants and enabled to differentiate between experienced wheelchair users and less experianced. Wheelies are used in numerous situations, and skilled wheelie technique reflects an intimate connection with the wheelchair[7]. The Wheelie test encourages the participants to master their wheelie up to perfection, in order to integrate and coordinate the wheelchair, the body and the environment for optimal mobility.

Positive correlation indicated that participants who were anxious while performing the TOWM were also anxious while performing the Wheelie test. Psychological variables as anxiety should be measured and be considered when assessing wheeled mobility. It may be possible to use the TOWM and the Wheelie test anxiety scores to predict individuals with greater difficulty in adjustment following a spinal cord injury.

Results based on the ability, quality and anxiety scores confirmed that the Wheelie test may predict the TOWM *(Predictive validity).* These results suggest a link between mastering a wheelie and functional wheelchair skills. Training wheelie skills might be an indirect form of training functional wheelchair skills that will also increase confidence and perceived self-efficacy. Based on the prediction power of the wheelie test, as verified in the current study, it is advised to test if training wheelie skills will result in an improvement in the functional outcomes of the TOWM tasks. A positive result, may suggest that the shorter and more economical Wheelie test may serve as an excellent alternative for the TOWM.

The significant correlation found between both test's ability, quality and anxiety scores with 'time since injury' and with 'perceived self-efficacy in wheeled mobility' (*Construct validity*) is only logical, since more years of experience, will probably lead to a better wheeled mobility performance, and successful wheeled mobility experience over the years, will increase self-efficacy in wheeled mobility perceptions. There might be a critical amount of experience necessary in order to reach one's maximal wheeled mobility level. But it is also possible that the high correlations between wheeled mobility and 'time since injury' as found in this study were because wheeled mobility skill training in rehabilitation was not optimal. It could be that providing excellent and intensive wheeled mobility skill training during rehabilitation would bring the patient close to maximal wheeled mobility performance. If this would be the case, correlations between wheeled mobility and time since injury would be lower. This assumption should be tested in a follow-up intervention study.

The significant fair to good correlations found between wheeled mobility (tested with the TOWM and the Wheelie test ability, quality and anxiety scores), and perceived self-efficacy, is consistent with the result reported by Horn et al. (1998)[19], who found in their retrospective study that self-efficacy was significantly associated with degree of impairment and disability.

The large distinction in wheeled mobility performance between people who are active in sport and those who do not can be easily explained; studies confirmed that athletes with a spinal cord injury hold higher wheeled mobility perceptions, compared to none-active wheelchair users[12]. Participation in sports, especially dynamic wheelchair team sports, promotes interaction with other people in similar situations and may improve wheeled mobility techniques[13]. It can be expected that sport activity itself has a positive impact on wheeled mobility skill level through an increase in strength, aerobic capacity, functional independence and a general healthy lifestyle. Furmaniuk et al.[20] reported significant functional changes, following two years participation in wheelchair rugby training, measured by the Wheelchair Skills Test version 2.4 (WST)[15], in patients with all levels of spinal cord injury.

Study limitations and further research

In this study, only associations were investigated; no causal relations as well as direction of associations were discerned among a relatively homogeneous and small group of manual wheelchair users with a spinal cord injury only. Another limitation of the study is the small sample size and the absence of females in the sample. In addition, it is unclear whether both tests are applicable in early rehabilitation. The validity of the tests should be investigated in a larger and more diverse sample, including spinal cord injured patients – males and females – during their rehabilitation period. The TOWM and the Wheelie test should also be used to assess the effectiveness of intervention programs in a randomized controlled trial. Further research should focus on deriving norms according to lesion level. This should enable clinicians and researchers to make a better prediction about someone's maximal achievable functional level of wheeled mobility.

For clinical practice it is possible to recommend an integration of all the wheelchair skills presented in the TOWM into wheelchair training programs, since these skills were considered to be the most relevant for participation in daily life. The quality assessment sheet can be a useful tool in guiding the wheelchair users into a more mature skill performance.

To conclude, the TOWM and the short Wheelie test are feasible and valid tests, evaluating wheelchair users with a spinal cord injury, in daily wheeled mobility skills. We expect that eventually, one wheeled mobility skill test will be adopted by the rehabilitation community worldwide, and will be applied regularly, in order to derive norms and standards for wheeled mobility in spinal cord injury.

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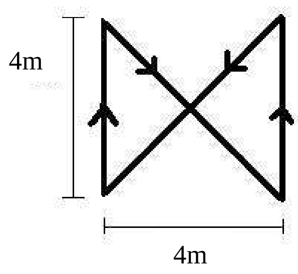
Appendix 1

A. Test of Wheeled Mobility (TOWM)

0 1 2 3 4 5 6 7 8 9 10

No anxiety **Maximal anxiety**

Note: **Before** performing each task, please ask the participant, to indicate on the 'anxiety scale', how anxious he is regarding performing this specific task. Anxious in this context does not mean anxious to fail the task but relatively to hurting one self.

1. Level propulsion forward (turns)	
Preparations: Place four cones in a square with sides of 4m. The participant is positioned in standstill next to the first cone behind a line. **Instructions:** “Accelerate as fast as possible throughout the circuit as shown in the figure. Timing starts and stops when the front wheels cross the starting line”.	**Measurements:** Ability Score: (yes/no), Reason (if not) Qualitative score (0-5) Time Score (s) Anxiety score (0-10)
Task in figure: 	

2. Level propulsion forward (one hand)	
Preparations: Place 2 cones 10 meters apart. A straight line should connect both cones. Start and finish lines are marked vertically; The participant is positioned in standstill next to one of the cones. **Instructions:** "Move as fast as possible from line 1 to line 2 keeping the 10m line between the wheels. The preferred hand is only allowed to touch the rims on the side of the hand itself.” Timing starts and stops when the front wheels cross the marked lines.	**Measurements:** Ability Score: (yes/no), Reason (if not) Qualitative score (0-5) Time Score (s) Anxiety score (0-10)

3. Ascending / descending sidewalk starting with front wheels in front of a step (5cm, 10cm, 15cm, 20cm)

Preparations: The platform (starting with 5cm) is placed against the wall with the sharp edge. A 30 cm line is marked before the platform.

Instructions: “Place the front wheels in between the marked line and the platform and ascend it. Turn around but be aware that the platform is narrow, and descend the platform smoothly, keeping the wheelchair all the time under control”.

Safety Note: examiner stands close and behind the participant, both hands are ready to catch the chair to avoid falling backward

Measurements:
Ability Score: (yes/no), Reason (if not)
Qualitative score for the 10cm tasks (0-5)
Maximal height (cm)
Anxiety score (0-10)


4. Ascending a sidewalk, starting with a run-up of 3m (5cm, 10cm, 15cm, 20cm)

Preparations: The platform (starting with 5cm) is placed against the wall with the sharp edge. A tape marks the 3m run-up.

Instructions: “Place the front wheels behind the marked line, move towards the platform and ascend it”.

Safety Note: examiner stands close to the curb and behind the participant, both hands are ready to catch the chair to avoid falling backward

Measurements:
Ability Score: (yes/no), Reason (if not)
Qualitative score for the 10cm tasks (0-5)
Maximal height (cm)
Anxiety score (0-10)



5. Going up & down a ramp (8% [10cm], 12% [15cm], 16% [20cm], 24% [30cm], 32% [40cm], 40% [50cm])

Preparations: The platform (starting with 10cm) is placed against the wall with the sharp edge. Place one end of the portable ramp on the ground and the other end on top of the wooden plate and fix with screws. The participant is positioned with the front wheels on the platform.

Measurements:
Ability Score: (yes/no), Reason (if not)
Qualitative score for A-30 cm, B & C tasks (0-5)
Maximal height (cm) with / without run up
Anxiety score (0-10)

Instructions A: "Go up the ramp in a straight line, turn around on the platform, go downhill and return to the floor, descend the way you like, if you consider a wheelie being necessary going down, then do so."

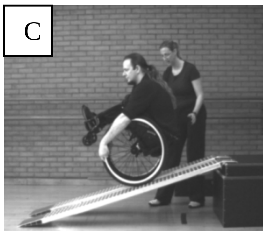
The level where the participant fails can be repeated with a run-up of 5m.

Instructions B: "Try to ascend the height you failed again with a run-up of 5m."

The last level succeeded will be repeated and the participant has to stop in wheelie while descending.

Instructions C: "Go up the ramp in a straight line, turn around on the platform, go downhill in a wheelie and stop in the middle of it, keep the wheelie for 3 seconds, continue downhill and return to the floor"

Safety Note: examiner stands close to the ramp and behind the participant, both hands are ready to catch the chair to avoid falling backward, a safety guard is needed.



6. Transfer from a wheelchair to another comparable wheelchair

Preparations: Place a second wheelchair next to the participant's wheelchair in a position as preferred.

Instructions: "You are asked to perform this task 2 times in different conditions. In the first trial you may transfer yourself from a stable to an unstable chair. In the second transfer task, you will be asked to transfer from an unstable chair to another unstable chair also in a position of your choice".

Measurements:
Ability Score: (yes/no), Reason (if not)
Qualitative score for stable to unstable chair (0-5)
Anxiety score (0-10)

B. The Wheelie test

1. Stationary wheelie	
Preparations: A clear space on an even surface of at least 4 Sqm (2m X 2m). **Instructions:** “Lift up the front wheels and balance stationary only on the rear wheels during 15 seconds using two hands.” **Safety Note:** examiner stands close and behind the participant, both hands are ready to catch the chair to avoid falling backward	**Measurements:** Ability Score: (yes/no), Reason (if not) Qualitative score (0-5) Anxiety score (0-10) 
2. One handed wheelie	
Preparations: A clear space on an even surface of at least 4 Sqm (2m X 2m). **Instructions:** “Lift up the front wheels, using only one hand (place the other hand on your lap) and balance stationary only on the rear wheels. As soon as you gained balance continue for 15 seconds in the wheelie using only one hand”. **Safety Note:** examiner stands close and behind the participant, both hands are ready to catch the chair to avoid falling backward	**Measurements:** Ability Score: (yes/no), Reason (if not) Qualitative score (0-5) Anxiety score (0-10) 
3 + 4. Rolling wheelie forward and backward	
Preparations: A clear space on an even surface of 10m. A cone is placed near the 10m mark. (The command “Go” when all 4 wheels on the floor) Timing starts and stops when the front wheels cross the marked lines. **Instructions A:** "Lift up the front wheels and balance on the rear wheels only. Move 10m forward as fast and as safe as possible. **Instructions B**: "Lift up the front wheels and balance on the rear wheels only. Move 10m backward as fast and as safe as possible. **Safety Note:** examiner stands close and behind the participant, both hands are ready to catch the chair to avoid falling backward	**Measurements:** Ability Score: (yes/no), Reason (if not) Qualitative score (0-5) Time Score (s) Anxiety score (0-10)

5. Circle forward 2 hands

Preparations: A clear space on an even surface of at least 9 Sqm (3m X 3m) and a cone. Starting line defining when the circle starts and ends.

Instructions: "Bring the wheelchair into wheelie. Make one complete circle forward around the cone; Do not make a turn in place. The task is finished when crossing the starting line.

Safety Note: examiner stands close and behind the participant, both hands are ready to catch the chair to avoid falling backward

Measurements:
Ability Score: (yes/no), Reason (if not)
Qualitative score (0-5)
Anxiety score (0-10)

6. Negotiating uneven surface in a wheelie

Preparations: The 6 threshold ramps are placed as shown in the figure (The command “Go” when all 4 wheels on the floor)

Instructions: “Bring the wheelchair into wheelie. Go over the 6 thresholds without letting the front wheels touch the ground, do it as fast and as safe as possible, but be aware you have only 1 trial so don't fall”. Timing starts and stops when the front wheels cross the marked lines.

Safety Note: examiner stands close and behind the participant, both hands are ready to catch the chair to avoid falling backward

Measurements:
Ability Score: (yes/no), Reason (if not)
Qualitative score (0-5)
Time Score (s)
Anxiety score (0-10)

<table>
<tr><td colspan="2">7. Accelerating and stop in wheelie</td></tr>
<tr><td>Preparations: 15m of clear space on an even surface. Position the participant 10m from a clear line marked on the floor, while ensuring at least 3m of clear space (marked on the floor) behind the mark. (The command “Go” when all 4 wheels on the floor)

Instructions: “Accelerate as fast as possible towards the 10m line and when you reach the line in maximum speed, stop the wheelchair in a wheelie position without losing control and keep the wheelie controlled for 3s”.

Safety Note: the examiner should stand close to the line marked on the floor, ready to help in case of losing the balance.</td><td>Measurements:
Ability Score: (yes/no), Reason (if not)
Qualitative score (0-5)
Time Score (s) from start to crossing 10m line
Anxiety score (0-10)
</td></tr>
<tr><td colspan="2">8. Backward over 5cm step in a wheelie</td></tr>
<tr><td>Preparations: Place the 5cm platform against the wall with the sharp edge. Place the yoga mat on top, 30 cm from the rounded edge. Position the participant with his back against the platform.

Instructions: “Start in a wheelie with the rear wheels against the curb. Go backward over the curb, controlling the wheelie. When the entire wheelchair is on top of the platform, keep the wheelie controlled for 3s and then bring down the front wheels.”

Safety Note: the examiner should stand close to the participant and behind him, ready to help in case of losing the balance</td><td>Measurements:
Ability Score: (yes/no), Reason (if not)
Qualitative score (0-5)
Anxiety score (0-10)

</td></tr>
</table>

Appendix 2

A. TOWM and Wheelie test score sheet (ability and performance time score)

Name or subject ID	Assessment date	Name of examiners
………………………	…/…/………	………………………

Part 1: Personal Information

1. Date of birth	…/…/……	13. Neurological level		R	L
2. Date of injury	…/…/……		Sens		
3. SEWM-score			Mot		
4. Height (m)		14. Zone of partial preservation		R	L
5. Weight (kg)			Sens		
6. Wheelchair Weight (kg)			Mot		
7. BMI (kg/m²)		15. ASIA Impairment scale			
8. PASIPD score (MET-hr/d)		16. Complete/Incomplete			
9. Center of gravity	Angle (°)				
	Dist. (cm)				
	Front Wheel Weight (kg)				
	X & y				

Part 2: TOWM	Anxiety (VAS)		Why not? / Remarks	Ability (1/0)		T		Q
1. Level propulsion forward (4x4)								
2. One hand propulsion (10m on a marked line)								
3. Ascend sidewalk 5cm (start between 30cm line)								
4 Descend sidewalk 5 cm								
5.Ascend sidewalk run up 5cm (3m run up)								
6. Ascend sidewalk 10cm								
7. Descend sidewalk 10 cm (help Asc. If need)								
8. Ascend sidewalk run up 10cm								
9. Ascend sidewalk 15cm								
10. Descend sidewalk 15 cm								
11. Ascend sidewalk run up 15cm								
12. Ascend sidewalk 20cm								
13. Descend sidewalk 20 cm								
14. Ascend sidewalk run up 20cm								
15. Up a slope 5% (10cm) (front wheels on ramp)								
16. Down Slope 5% (10cm)								
17. Up a slope 7.5% (15cm)								
18. Down a slope 7.5% (15cm)								

Part 2: TOWM - continued	Anxiety (VAS)		Why not? / Remarks	Ability (1/0)		Time/ Height		Q
19. Up a slope 10% (20cm)								
20. Down a slope 10% (20cm)								
21. Up a slope 15% (30cm)								
22. Down a slope 15% (30cm)								
23. Up a slope 20% (40cm)								
24. Down a slope 20% (40cm)								
25. Up a slope 26% (50cm)								
26. Down a slope 26% (50cm)								
27. Down a slope, stop in wheelie (last succeeded, with run up, write height)								
28. Up a slope with a run up (last failed, write height)								
29. Chair transfer stable - unstable								
30. Chair transfer unstable-unstable								

Part 3: The Wheelie test	Anxiety (VAS)		Why not? / Remarks	Ability (1/0)		T		Q
1. Stationary (15 sec)								
2. One handed wheelie (15s hand face the camera)								
3. Forward 10m ("Go" with 4 wheels on floor)								
4. Backward 10m ("Go" with 4 wheels on floor)								
5. Circle forward (around a cone)								
6.Uuneven surface ("Go" - 4 wheels on floor)								
7. Accelerate and stop in wheelie (Time score from start line to crossing 10m)								
8. Backward over curb 5cm								

Total outcome measures

	Part 2: TOWM	Part 3: Wheelie test	Total
Total Ability score			
Total Time score			
Total Anxiety score			
Total quality score			
Max. curb height			
Maximal slope			

Ability score: (yes=1,no=0)
Why not: reason to refuse
Anxiety score (0-10)
T=Time score (seconds)
H=Height (cm)
Q=Quality score (0-5)
Asc = Ascend
Sens = Sensor
Mot = Motor

B. TOWM Quality Score sheet

Name or subject ID	Assessment date	Name of examiner
………………………	………………………	………………………

TOWM tasks	Performance criteria	
1. Level propulsion + turns forward (4X4)	• **SP***: grasps/frictions rims or tires at the highest point and bends forward • **Arms**: Push with two arms simultaneously • **Upper body:** moves forward approx. 10° or more when speeding up. • **Trunk** in turns: upright and bent laterally to the side of the turn, turning as close as possible to the cone • **Hands** in turns: slow down the inner wheel, pushes the outer wheel forward while completing the turn	☐ ☐ ☐ ☐ ☐
2. One hand propulsion (10 meters)	• **SP**: grasps rim or tires at the highest point with the pushing hand, upper body remains in natural position • **Upper body:** shifts weight towards the pushing side • **Pushing hand**: presses rim down, simultaneously to the creation of the peak compensation momentum from the opposite shoulder/upper body • **At the end** of the push, at 2 o'clock position, trunk and hand are back in starting position • **General Quality Note:** Maintain the same rhythm and speed throughout the task	☐ ☐ ☐ ☐ ☐
6. Ascend 10cm sidewalk	• **SP**: front wheels are slightly raised above the step and immediately placed on it • **Trunk**: bends forwards when placing down the front wheels • **Arms**: push with both arms symmetrically downward at the front of the rear wheels, when the front wheels come down • **Trunk** Straightened as soon as the rear wheels get on the step and the front wheels are lowered • **General Quality Note:** Ascend the sidewalk symmetrically, in one confident push	☐ ☐ ☐ ☐ ☐
7. Descend 10 cm sidewalk	• **SP:** approaches the edge while staying on rear wheels • **Hands**: Push forward and breaking while lowering the wheelchair • **Pelvic/lower trunk:** pushed against the backrest • **At the end:** rear wheels contact the ground **first**, while **controlling** the wheelie, before placing front wheels down • **General Quality Note:** Descend the sidewalk symmetrically , in an elegant and smooth landing	☐ ☐ ☐ ☐ ☐
8. Ascend 10cm sidewalk with a 3 meters run up	• **SP**: 2-3 pushes forward, **pelvic and lower trunk** are lowered and pushed against the backrest when reaching the step • **General Quality Note:** utilize the outcome run-up inertia to ascend the sidewalk without slowing down • **Trunk**: bends forwards when places down the front wheels • **Arms**: push downward at the front of the rear wheels, when the front wheels come down • **Trunk** Straightened as soon as the rear wheels get on the step and the front wheels are lowered	☐ ☐ ☐ ☐ ☐

21. Up a slope 15% (30cm)	• **SP**: Leaning forward, places hands towards the back of the top of the tire • **Hands**: push forward and downward • **Elbow:** Flex the elbow repetitively in the same angle (angle is proportional to the incline of the slope) • **Hands**: Shortest recovery time • **Trunk and head** remains in the same leaning forward position while ascending	☐ ☐ ☐ ☐ ☐
22. Down a slope of 15% (30 cm)	• **SP**: pushes forward until the rear wheels touch the ramp • **Pelvic/lower trunk:** pushed against the backrest, adapts wheelchair decline position to the slope (the steeper the slope, the more inclination is needed) • **Hands**: allows rims glides through, in a controlled movement, keeps the acceleration constant until the desired speed is achieved • Hands places at the front of the tires/rims to control the speed in braking movements • **General Quality Note:** prefers to descend in a wheelie, rear wheels touch the floor first.	☐ ☐ ☐ ☐ ☐
27. Down a Slope stop in a wheelie for 3 sec.	• **SP**: Pushes forward until the rear wheels are over the edge • **Pelvic/lower trunk:** pushed against the backrest, adapts wheelchair decline position to the slope (the steeper the slope, the more inclination is needed) • **Hands**: allow rims glides through, in a controlled movement, Keeps the acceleration constant until the desired speed is reached • **Elbows**: to stop in wheelie, the elbows extend nearly to about 135° • **Head:** flex a bit forward during the wheelie	☐ ☐ ☐ ☐ ☐
28. Up a slope with a 5 meters run up	• **SP**: 2-3 pushes forward, Leaning forward when reach the ramp • **General Quality Note:** utilize the outcome run-up inertia to ascend the slope without slowing down • **Hands**: push downward, shortest recovery time • **Upper trunk and head:** leaning forward maximally (no contact with the backrest) • **Elbow:** Maximal flexion when nearly reaching the top	☐ ☐ ☐ ☐ ☐
29. Chair Transfer stable to unstable	• **SP**: Checks the position of the feet: flat on the floor and vertically beneath the knees so that the weight is over them • **Head and shoulders:** flexed throughout the transfer • **Hands:** one on the armrest or on the seat and the other on the seat of the other chair, lifting up • **Foot:** places the foot on the footplate • **General Quality Note:** transfer at once, (placing the pelvic directly on the next chair seat in one movement)	☐ ☐ ☐ ☐ ☐

C. Wheelie test Quality Score sheet

Wheelie test tasks	Performance criteria	
1.Stationary	• **SP:** Hands placed on the wheels in approximately the 10 o'clock position* • **Upper body**: stays still when the **hands** are pushed forward, the **head** bends slightly forward • **Hands** are in the 2 o'clock position, **Elbow**: approximately 140° flexion • **Hands**: Maintains position and balance, keeping the body completely still • **General Quality Note:** gets into balanced wheelie in less the 2 seconds	☐ ☐ ☐ ☐ ☐
2. One handed wheelie	• **SP:** 1 Hand placed on the wheels in approximately the 10 o'clock position • **Upper body**: stays still when the one **hand** is pushed forward, the **head** bends slightly forward • **Hand** is in the 2 o'clock position and approximately 140° flexion in the elbow • **Head:** Maintains position and balance, keeping the body completely still • **General Quality Note:** gets into balanced 1 handed wheelie in less the 3 seconds	☐ ☐ ☐ ☐ ☐
3. Forward 10m in a wheelie	• **SP:** Hands placed on the wheels in approximately the 10 o'clock position • **Hands** are in the 2 o'clock position, **Elbow**: approximately 140° flexion to maintain the wheelie position • **Trunk and Head:** brings a little bit forward simultaneously to the pushing forward • **Hands:** brings immediately back to 10 o'clock position (short recovery time) • **General Quality Note:** maintain the same speed and the same front wheels height throughout the task	☐ ☐ ☐ ☐ ☐
4. Backward 10m in a wheelie	• **SP:** Hands placed on the wheels in approximately the 10 o'clock position • **Upper body**: stays still when the **hands** are pushed forward into wheelie position • **Arms** push backward; simultaneously bring the **upper body** a little bit backward as well, while keeping the **head** bent forward to avoid falling back. • Brings **hands** immediately back to 2 o'clock position **without rolling forward** • **General Quality Note:** maintain the same speed and the nearly the same front wheels height throughout the task	☐ ☐ ☐ ☐ ☐
5. Circle forward in a wheelie	• **SP:** Hands placed on the wheels in approximately the 10 o'clock position**,** **Upper body**: stays still when the **hands** are pushed forward into wheelie position • **Hands when turning,** hold the inner wheel and push the outer wheel forward, when both hands are pushing, the **outer elbow** is flexed more and pushing harder • **Upper body**: Bend laterally to the side of the turn • **General Quality Note:** maintain the same speed and make the turn as close as possible to the cone • **Finishing:** control the final movement and brings the front wheels down in controlled way	☐ ☐ ☐ ☐ ☐

6. Uneven surface in a wheelie	• **SP:** Hands placed on the wheels in approximately the 10 o'clock position**,** **Upper body**: stays still when the **hands** are pushed forward into wheelie position • **Hands:** Push forward, maintain balance by alternately performing flexion and extension in the elbows, while keeping the rest of the body still • **Head and upper body:** while pushing forward, bring the upper body and head a little bit forward simultaneously, keeping the lower trunk pushed against the backrest • Brings **hands** immediately back to 2 o'clock position after crossing each obstacle • **General quality Note:** maintain the same speed throughout the task	☐ ☐ ☐ ☐ ☐
7. Accelerate and stop in wheelie	• **SP:** Accelerate as fast as possible • **Head and trunk:** when crossing the line, goes at once into wheelie by extending the head and the trunk and jerkily generate a last 1 push • **Arms:** Braking as fast as possible (minimal distance behind the line) by keeping the arms flexed • **Hip:** Tilting the chair to the maximum (to brake maximally) by extreme hip flexion • **Finishing:** as soon as the chair reaches standstill, hips go back in neutral wheelie position	☐ ☐ ☐ ☐ ☐
8. Backward over 5cm curb/stop in a wheelie	• **SP:** Go into wheelie, oriented backward to the step, drives slowly backwards in wheelie until both wheels touch the step • **Hands** are moved forward on the hand rims until the elbows are almost in full extension • **Trunk** is flexed • **Hands**: inclining backwards 'en-bloc' (pulling force brings wheelchair on the step), while the trunk **remains** flexed forward • **Finishing:** on top of the step, trunk returns into wheelie neutral position	☐ ☐ ☐ ☐ ☐

*SP: starting position
*10 o'clock position /2 o'clock position: evaluator facing the right wheel

Total score: **TOWM: _______________ Wheelie Test: _______________**

Chapter 8

The reliability of the Test of Wheeled Mobility (TOWM) and the short Wheelie test

Fliess-Douer O, van der Woude LH, Vanlandewijck, YC, (2012). The reliability of the Test of Wheeled Mobility (TOWM) and the short Wheelie test. *The Archives of Physical Medicine and Rehabilitation*, Submitted for publication.

ABSTRACT:

Objective: To assess the reliability of the Test of Wheeled Mobility (TOWM) and the Wheelie test

Design: Cohort study Test-retest (t1-t2)

Participants: Thirty manual wheelchair-users with a spinal cord injury

Intervention: Participants performed the 30 skills of the TOWM and 8 skills of the Wheelie test twice. Ability, time and anxiety scores were assessed on-field. Quality scores were assessed by video analysis.

Main outcome measure: Test-retest reliability was evaluated for all 4 scores of both tests. Intrarater and interrater reliability were determined based on the quality scores of 20 participants. Intraclass coefficient and non-parametric statistics were applied, as well as standard error of measurement (SEM), method error (ME), coefficient variation of method error (CV_{ME}), minimal detectable change (MDC_{95}), and technical error of measurement (TEM),

Results: Test-retest reliability: no significant differences between t1 and t2 in the ability, quality and time scores, except to the anxiety scores. SEM, ME CV_{ME} and MDC_{95} values were low for the ability and quality total score and higher for the time and anxiety total score. Intrarater and interrater reliability ICC's of both tests ranged between 0.91-0.99. Interrater relative TEM for the TOWM and the Wheelie test total quality score was 3.7% and 6.3% respectively and intrarater relative TEM was 4.3% and 6.1%. ICC's per individual tasks, ranged between 0.88-1.00, except for 'level propulsion forward' that showed low ICC scores (Interrater: 0.49; intrarater: 0.44; test-retest: 0.43).

Conclusions: Based on ability and quality total scores, the TOWM and the Wheelie test are reliable when assessing wheeled mobility of manual wheelchair users with SCI. The quality criteria of one task from the TOWM and three tasks from the Wheelie test need to be further refined.

Key words: Wheeled mobility, spinal cord injury, wheelchair skills, reliability

INTRODUCTION

Spinal cord injury (SCI) is a condition that severely disables a person. Reported incidence of SCI varies between 10.4 and 83 per million inhabitants per year[1]. A distinction is made between tetraplegia and paraplegia and a complete and incomplete injury, based on ASIA definitions[2]. An estimated one-third of the patients with SCI have tetraplegia and 50% of patients have a complete SCI. In the worldwide literature review of Wyndaele and Wyndaele, the mean age of patients sustaining their injury is reported as 33 years old, and the gender distribution men/women as 3.8/1[1].

SCI will have an impact on the physical, social as well as the emotional aspect of the injured person. Learning wheelchair skills performance is an important part of the rehabilitation process, since for a large group of people with SCI, the wheelchair will serve as the main device for mobility.

Wheeled mobility (WM) is defined by the International Classification of Function (ICF) as "Moving around using equipment: moving the whole body from place to place, on any surface or space, by using specific devices designed to facilitate moving or create other ways of moving around, such as moving down the street in a wheelchair or a walker" [3]. If WM of a person is increased, it can be assumed that the quality of life and closely related to it, well-being, will increase as well[4].

Therapists should have a valid, reliable and sensitive measuring tool at their disposal, in order to objectively and systematically assess their patient's level of WM performances, before, during and after interventions. Nowadays there are several wheelchair skills tests available, based on actual performance[5-17]. All of these tests highlight different aspects of functioning as a wheelchair user with a SCI (e.g. dressing, eating, riding a slope, etc.). In addition, different scaling is applied to express test scores. Some tests use qualitative scales, while others use quantitative scales; as a result, comparison between studies is difficult, if not impossible. The quantitative measurement can be, for example, the time necessary to complete a task or the percentage of a slope. The qualitative measurement has to be well defined. It is not sufficient to apply only a pass/fail scale, because the same level of difficulty can be completed with a different grade of maturity. In this case, it can be useful to incorporate the term "with difficulties", or to combine also time scale (quantitative and qualitative measurements within the same test). Still, these scales might not be sensitive enough to detect small changes in WM[18] because they only record whether a person can perform a particular task or whether the task is performed independently. Small improvements in the quality of the skill performance can often not be scored. Nonetheless, these small changes can be of great importance. The way to overcome this problem would be through developing quality assessment criteria for each WM skill. These criteria (based on key components which compose the skill) will reflect the WM maturity proficiency.

Within the scope of a study aimed to promote a standardized broadly accepted and applicable WM test, the Test of Wheeled Mobility (TOWM) and the short Wheelie tests were developed[19]. The development of these two tests was based on expert opinions, and international survey among users. In addition, a systematic critical literature review of available wheeled mobility skill test enabled the development of the new WM tests, relying on strengths of the existing tools[18]. The purpose of the TOWM and Wheelie test is to assess WM in manual wheelchair users with SCI during and after clinical rehabilitation allowing accurate and valid monitoring and assessment of small changes in skill. The TOWN and Wheelie test are primarily designed for clinical purposes but may also be used in a research setting. Both assessment tools were tested for their feasibility and validity with respect to duration, costs, content, construct, concurrent and predictive validity[19]. The TOWM consists of 30 standardized tasks which are conditional to mobility in persons with SCI[19]. The short Wheelie test includes 8 tasks which are related to the ability to perform a mature pattern of a wheelie (balancing on the rear wheels). The TOWM and the Wheelie test tasks present different difficulty levels and are applied from the easiest to the most difficult. Different from earlier WM performance-based tests[5-17], both tests have 4 scoring scales: ability score, performance time score, anxiety score and quality score[19]. Including preparation and evaluation time, the estimated duration of both tests together is 40 minutes (Mean ± SD for the TOWM 24.7±5.93 min., and for the Wheelie test 12.62±5.08 min.), including equipment preparations, instructions for each task and performance of the test[19]. The protocols of the TOWM and the Wheelie test with description of the tasks as well as testing equipment and score sheets can freely obtain at: www.scionn.nl/inhoudp28.htm.

The reliability of any new measurement instrument is critical to ensure that the measurement error is small enough to detect actual changes in what is being measured[20]. The aim of this study was to assess the test-retest and the inter-and intrarater reliability of TOWM and the Wheelie test. A specific focus was targeting the reliability assessment of the newly developed quality scale; this scale is additional to the ability and performance time score and based on a process-oriented assessment and maturity pattern of skill performance. For each skill of the TOWM and the Wheelie test, five components were selected as the most important quality "performance criteria". If a participant perfectly accomplishes these 5 components while performing a task, it constitutes a 'mature pattern of the skill'. This scoring method offers a meaningful feedback regarding how well one preformed each WM task, what exactly were the mistakes and how mature was the overall quality of his WM performance.

To test the reliability, the following three hypotheses were tested: 1) Test-retest reliability: there will be no significant change in the TOWM and in the Wheelie test scores between the two test sessions (t1 and t2); 2) Intrarater reliability: there will be no significant differences in the TOWM and the Wheelie test quality scores between the two evaluations done by the same rater; and 3) Interrater reliability: two examiners will show high agreement when scoring the quality scores of the TOWM and the Wheelie test.

METHODS

Participants

Thirty wheelchair users with a SCI (convenience sample) were recruited during the first 2 weeks of February 2011. Recruitment was performed by word of mouth, email and telephone calls. All participants were living in Belgium, were out of clinical rehabilitation, used a hand-rim wheelchair, and were between 18 and 65 years of age. Potential participants were not included if they had a current cardiorespiratory disorder or orthopedic or other medical complications that restricted them in performing the tasks required for the TOWM and the Wheelie test. One participant did not attend the retest (t2) due to a recurrence of an old shoulder injury unrelated to the WM-testing; therefore, the results of 29 participants were included in the presented data analysis.

All procedures were performed in accordance with the guidelines of the Declaration of Helsinki. The study was approved by the medical ethics committee of the Catholic University of Leuven, Belgium. Prior to participation, all participants signed an informed consent.

Testing procedures

A test – retest procedure was undertaken. In test occasion 1 (t1), the research team explained about the study aims, asked the participants to complete a personal information form and to sign the consent form. Body dimensions (participant's weight, height and body mass index (BMI=weight (kg) × height $^{-2}$(m)), were also taken. Following these procedures, the research team introduced the course of the tests and ran both tests (TOWM followed by the Wheelie test). After 1 week from test occasion 1, all the participants were tested again (t2) at the same place, time of the day and by the same research team (Figure 1). Both tests were performed while using the personal ADL (activity of daily living) wheelchair. Inspection of the wheelchair configuration (e.g. the calculation of the wheelchair center of gravity) was performed at t1 and at t2, to ensure the use of the same wheelchair (configuration and condition) at both test occasions. Center of gravity was tested according to the formula $X = (F1 \times d) \times (m \times g)^{-1}$; $Y = X \times \text{cotg}(\text{angl}_{incl})$[20] (with F1 as the weight on the front wheels, d as the horizontal distance between rear and front wheel axle, and $m \cdot g$ as the total weight (person + wheelchair)). The y coordinate of COG (vertical coordinate) is calculated as: $Y = x \cdot \text{cotg}(\text{angl}_{incl})$. Angl_{incl} is determined by the angle over which the wheelchair-user system had to be inclined to decrease x to zero).

The participants were asked to refrain from smoking, drinking alcohol and caffeine products for at least 2 hours before each trial. For the quality assessment (done after the test), participants were videotaped by the same photographer, using the same camera (Canon Basler 100Hz Canon Inc., Tokyo, Japan), placed on a marked line (the test map is presented in Appendix 1)

Reliability assessment

Three raters (qualified and trained physical therapists) were involved in the reliability analysis (Figure 1). For both the test-retest and intrarater reliability assessment, the exact interval between the first and second rating was one week.

For test-retest reliability, rater number 1 scored during "real time" the ability scores, performance time scores and anxiety scores at t1 and at t2. The quality scores of a random selection 20 participant's videos taken at t1 and at t2 were assessed after the test, by rater number 2 (Figure 1). There was no attempt to stratify the sample on any basis as age, time since injury or sport participation.

However, we stratified the sample to ensure that we included in the sample a full range of lesion levels (i.e. individuals with tetraplegia, and with high and low paraplegia).

Intrarater reliability was assessed by rater number 2 who scored twice (repeatedly, one week apart) the same participants' videotapes (taken at t1). On the second evaluation, the rater was not permitted to review the results of his initial evaluation. Interrater reliability was determined using the quality scores obtained at t1 by two independent raters (rater number 2 and rater number 3) (Figure 1).

Statistical procedures

Descriptive statistic and reliability analysis were performed using SPSS (version 16.0, SPSS Inc., Chicago, USA) and Microsoft Excel 2010.

The nature of reality is such that due to instrument imprecision and human inconsistencies, measurements are not free of error (i.e. perfectly reliable). For measuring test-retest reliability, Wilcoxon signed-rank test was used to verify the absence of significant differences (systematic errors) between the measures at the two different times (t1 and t2). The interclass correlation coefficient (ICC) with a 95% CI was used as a measure of reliability for both, test-retest reliability as well as for inter- and intrarater reliability. A priori an ICC of 0.80 or higher was defined as an indication of good reliability[21].

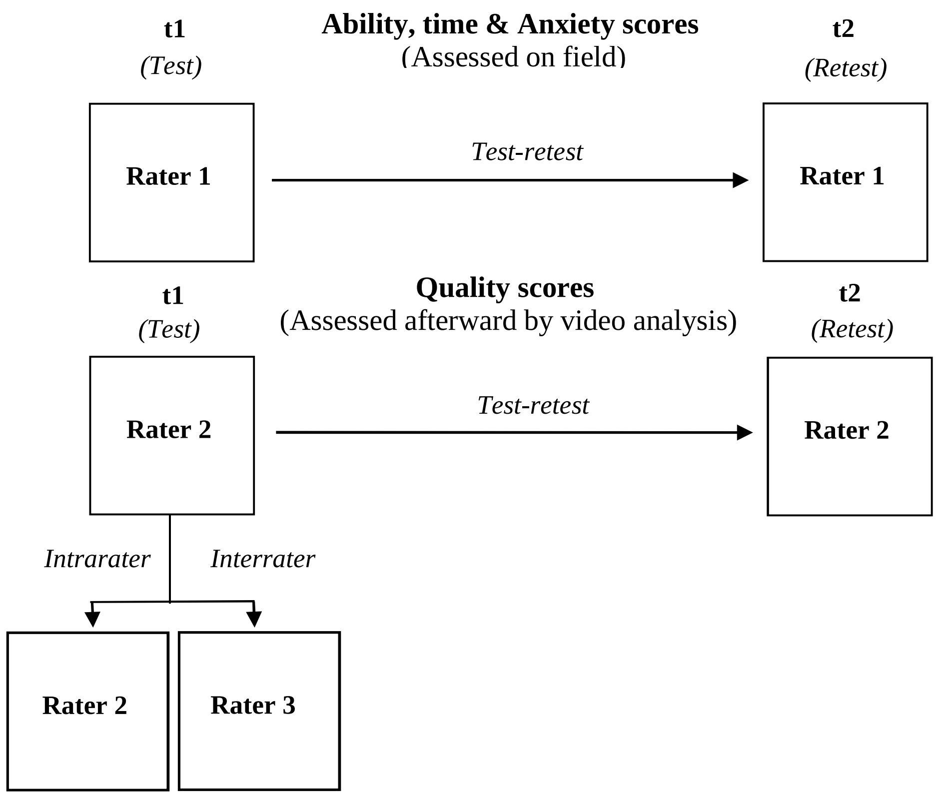


Figure 1: **test-retest, intrarater and interrater reliability**

In addition to measuring the reliability of instruments and raters, the consistency or stability of repeated participants' responses was assessed (Response stability). Response stability is basic to establish all other types of reliability, because if the response variable varies from measurement to measurement, it will not be possible to separate out errors due to the rater or instrument. Response stability was expressed in terms of Method Error (ME), Standard Error of Measurement (SEM) and coefficient of variation (CV_{ME})[22].

Method error (ME) is a measure of the discrepancy between two sets of repeated scores, or their difference scores. Large difference scores reflect greater measurement error. Method error is often used as an adjunct to test-retest correlation statistics, as it reflects the percentage of variation from trial to trial, which the correlation coefficient does not. In addition, unlike the correlation coefficient, method error is not affected by lack of variation in raw scores. Method error was calculated using the standard deviation of the difference scores between test and retest:

$$\mathrm{ME} = \frac{SD}{\sqrt{2}}$$

Method error should be interpreted relative to the size of the mean differences. Therefore, it was converted to percentages using the coefficient of variation:

$$CV_{\mathrm{ME}} = \frac{2ME}{\bar{X}_1 + \bar{X}_2} \times 100$$

The standard error of measurement (SEM) provides a value for measurement error in the same units as the measurement itself, i.e. it is an indication of absolute reliability[22]. This type of reliability is more clinically applicable on a day-to-day basis, rather than a relative reliability co-efficient value, such as an ICC, which is more difficult to interpret for clinical decision-making. The SEM was ~~also~~ calculated using the ICC values as reliability coefficient for the data[23]:

$$\mathrm{SEM} = \mathrm{SD} \times \sqrt{(1 - ICC)}$$

The SEM allows the calculation of the Minimal Detectable Change (MDC), which is an estimate of the smallest change in score that can be detected objectively for a client, i.e. the amount by which a patient's score needs to change to be sure the change is greater than measurement error[23]. The MDC was calculated to a 95% degree of confidence:

$$\mathrm{MDC}_{95} = \mathrm{SEM} \times \sqrt{2} \times 1.96.$$

The accuracy of the measurements was analysed by means of the technical error of measurement (TEM). The TEM index allows verifying the accuracy degree when performing and repeating measurements by the same appraiser (intrarater accuracy) and when comparing measurement with measurements from different appraisers (interrater accuracy)[24]. TEM was calculated using the formula:

$$\text{TEM} = \sqrt{\frac{\sum_D 2}{2N}}$$

Where: D is the difference between measurements and N is the total number of measurements taken. The TEM presents the same measurement unit (cm, mm, points) and at least 20 measurements are required[25].

RESULTS

The mean, SD and range scores of the TOWM and the Wheelie test are presented in Table 1. Because of various task difficulties, not all persons were able to perform all the tasks of the TOWM and the Wheelie test. If a participant was not able to perform a given task after two trials, an ability score of '0' was given and no time score was available. As a result, the group composition of participants differs slightly for the different four scales.

The mean age of the participants was 38.8 ±8.0 years and the time since injury was 12.4 ±10.5 years. The high values of these standard deviations (SD) demonstrate the large variability in the population group. SCI lesion level ranged from C5 – L1, (tetraplegia n=6, high paraplegia n=16, low paraplegia n=7). The mean Body Mass Index (BMI kg/m^2) was 24.2 ±3.9.

The mean age of the 20 participants that were qualitatively assessed was 39.9 ± 7.12 years (range 26-52 years) and time since injury was 13.2 ± 11.5 years (range 1-35). Mean and SD of the TOWM ability scores of that group was 19.9 ± 4.8 (range 13-28) and of the Wheelie test ability scores 5.6 ± 2.4 (range 0-8). No significant differences were found between the characteristics of the two subsample groups (i.e. in age, time since injury and lesion level).

The center of gravity (COG) did not differ between t1 and t2, ensuring the use of the same wheelchair setup at both tests occasions, and ICC's (consistency of the center of gravity examination done by the examiners at t1 and t2 for axis x and y) were high (0.92-0.98).

Test – retest reliability

No significant differences were found between t1 and t2 in the ability, quality and performance time total scores, supporting hypothesis 1. Only the anxiety scores showed significant differences between t1 and t2 (The VAS anxiety score was lower at the retest).

For the TOWM, the ICCs associated with the test–retest reliability varied from 0.91 to 0.99 and the 95% CIs from 0.80 to 0.99; (Table 1). For the Wheelie test, the ICCs associated with the test–retest reliability varied from 0.94 to 0.99 and the 95% CIs from 0.87 to 0.99.

Response stability indexes are presented in table 1. In general, response stability was higher for the ability and quality scales compared to the time scale. Anxiety scale had very low response stability, as expected due to the significant differences found between t1 and t2 in the anxiety total score

For the TOWM total scores, standard error of measurement (SEM) values were 0.63 point for the total ability score and 1.29 point for the total quality score. Time and anxiety total scores showed much higher SEM. Similarly, method error (ME) and coefficient variation of method error (CV_{ME}) values were low for both ability and quality total score and much higher for the time and anxiety total score. Minimal detectable change (MDC_{95}) values were 1.74 point for the total ability score and 3.59 point for the total quality score and much higher for the time and anxiety total score.

For the Wheelie test total scores, standard error of measurement (SEM) values were 0.44 point for the total ability score and 1.15 point for the total quality score. Time and anxiety total score showed higher SEM. Method error (ME) and coefficient variation of method error (CV_{ME}) values were low for the ability, quality and time total score and much higher for the anxiety total score. Minimal detectable change (MDC_{95}) values were 1.23 point for the total ability scores and 3.20 point for the total quality score and much higher for the time and anxiety total scores.

Table 1: **Mean scores and range of the four scales of the TOWM and the Wheelie test and test-retest reliability and responsiveness**

Scale	***n***	**t1** **mean (SD) [range]**	**t2** **mean (SD) [range]**	**t2-t1** **Mean diff.**	**Sig.**	**ICC**	**95% CI**	**SEM**	**ME**	**CV_{ME}**	**MDC_{95}**
TOWM											
Ability score (*scale 0-30)*	29	20.6 (4.5) [11.5-28]	20.8 (4.5) [11.5-29]	0.2	0.34	0.98	.96-.99	0.63	0.88	4%	1.74
Quality score (scale 0-50)	20	28.8 (13.5) [7-48]	28.6 (12.7) [7-44]	0.2	0.81	0.99	.99-.99	1.29	1.16	4%	3.59
Time score (*in sec.)*	15	17.6 (8.3) [10.9-41]	17.5 (8.3) [9.6-39]	-0.1	0.82	0.94	.88-.97	5.73	9.08	26%	15.87
Anxiety score *(VAS 0-10 X 30 items)*	29	14.6 (21.5) [0-66]	8.7 (16.4) [0-71]	-5.9	0.01*	0.91	.80-.95	5.75	7.93	68%	15.93
Wheelie test											
Ability score (*scale 0-8)*	29	5.2 (2.3) [0-8]	5.5± (2.2) [0-8]	0.3	0.17	0.96	.91-.98	0.44	0.62	12%	1.23
Quality score (*scale 0-40)*	20	17 (11.9) [0-35]	16.5 (11.5) [0-37]	-0.5	0.15	0.99	.99-.99	1.15	1.38	8%	3.20
Time score (*in sec.*)	15	13.2 (5.5) [6.6-23.6]	12.6 (5.1) [6.9-23.9]	0.7	0.28	0.97	.92-.99	3.63	4.81	9%	10.07
Anxiety score *(VAS 0-10 X8 items)*	29	6.2 (10.7) [0-32]	4.7 (9) [0-36]	-1.5	0.08	0.94	.87-.97	2.41	3.27	62%	6.68

Wilcoxon signed-rank test was used to verify the absence of significant differences (systematic errors) between the measures at two different times (t1 and t2).
Sig: significant *p*-value <.05; ICC, Intraclass Correlation Coefficient; CI, Confidence Interval; SEM = Standard Error of Measurement; ME = Method Error;
CV_{ME} = Coefficient variation of method error; MDC_{95} = Minimal Detectable Change (95 confidence);

The results of the test-retest reliability for the quality scores, per task, are presented in the Table 2. Statistical significant differences between t1 and t2 were only found for the quality scores of the 'wheelie forward' task, but 'ascend sidewalk with a run up 10 cm', 'up a slope with a run up' and 'stationary wheelie', were nearly significant. The ICCs associated with the test–retest reliability for the TOWM and Wheelie test quality scores, per task, varied from 0.88 to 0.99 and the 95% CIs from 0.73 to 0.99, except for 'level propulsion forward' that had a lower ICC (0.43).

Examining the per task response stability indexes, showed lower stability while preforming 'level propulsion forward' and 'one handed propulsion' of the TOWM, and 'one handed wheelie' of the Wheelie test. Minimal detectable change (MDC_{95}) was higher for the first two tasks of the TOWM and Wheelie forward 10 m of the Wheelie test.

Table 2: **Test-retest reliability of the quality scores per task (*n*=20)**

Task	**t1 Mean ± SD**	**t2 Mean ± SD**	**Sig.**	**ICC**	**95% CI**	**SEM**	**ME**	**CV_{ME}**	**MDC_{95}**
TOWM									
Level propulsion forward 4x4	4.3 ± 0.7	4.2 ± 0.6	0.56	0.43	-.43-.77	0.48	0.53	12%	1.34
One hand propulsion (10m)	2.8 ± 1.7	2.7 ± 1.7	0.41	0.88	.73-.95	0.57	0.45	17%	1.57
Ascend sidewalk 10 cm	0.8 ± 1.8	0.8 ± 1.8	1.00	1.00	1.00	0	0	0%	0
Descend sidewalk 10 cm	3.6 ± 1.7	3.7 ± 1.7	0.41	0.97	.93-.98	0.29	0.39	11%	0.80
Ascend sidewalk run up 10 cm	2.8 ± 2.4	3.0 ± 2.5	0.06	0.99	.98-.99	0.24	0.29	10%	0.67
Up a slope 15%	3.8 ± 1.6	3.9 ± 1.5	0.18	0.97	.93-.99	0.26	0.29	7%	0.73
Down a slope 15%	3.5 ± 1.6	3.6 ± 1.6	0.32	0.99	.98-.99	0.16	0.16	4%	0.43
Down a slope, stop in wheelie	2.1 ± 2.4	2.1 ± 2.4	1.00	1.00	1.00	0	0	0%	0
Up a slope with a run up	1.6 ± 2.1	1.5 ± 1.9	0.08	0.99	.97-.99	0.2	0.26	16%	0.55
Chair transfer stable	3.1 ± 1.8	2.9 ± 1.8	0.10	0.97	.94-.99	0.30	0.7	12%	0.84
Wheelie test									
Stationary wheelie	3.4 ± 1.3	3.5 ± 1.3	0.08	0.98	.95-.99	0.19	0.40	12%	0.52
One handed wheelie	1.2 ± 1.8	1.4 ± 2.0	0.18	0.98	.95-.99	0.27	0.53	40%	0.74
Wheelie forward 10 m	2.9 ± 1.9	2.4 ± 1.8	0.02*	0.94	.86-97	0.46	0.57	20%	1.27
Wheelie backward 10 m	1.9 ± 1.5	1.9 ± 1.6	0.56	0.98	.96-.99	0.22	0.36	19%	0.60
Circle forward	2.9 ± 2.0	2.9 ± 2.1	1.00	0.98	.95-.99	0.29	0.45	15%	0.81
Uneven surface	1.5 ± 1.7	1.2 ± 1.5	0.10	0.96	.88-.98	0.32	0.42	31%	0.87
Accelerate and stop in wheelie	1.7 ± 2.0	1.6 ± 1.9	0.32	0.98	.96-.99	0.26	0.42	28%	0.71
Backward over curb	1.4 ± 1.8	1.3 ± 1.7	0.56	0.98	.96-.99	0.26	0.39	27%	0.73

t1 = Test 1; t2 = Test 2 (Re-test); Sig: significant *p*-value <.05; ICC, Intraclass Correlation Coefficient; CI, Confidence Interval; SEM = Standard Error of Measurement; ME = Method Error; CV_{ME} = Coefficient variation of method error; MDC_{95} = Minimal Detectable Change (95 confidence);

The intrarater reliability

The results of the intrarater reliability for the quality scores per task are presented in the Table 3. None significant differences were found between the first and the second evaluation done by the same rater in the total quality scores of both tests, supporting hypothesis 2. The ICC associated with the intrarater reliability of both the TOWM and Wheelie test total quality score was 0.99.

Intrarater technical error of measurement (TEM) for the TOWM quality total score was 1.07, and 1.06 for the Wheelie test (Table 3), which corresponds to a relative TEM of 3.7% and 6.3% respectively.

The analysis of each task separately showed significant differences between the assessments of the 'uneven surface' and 'accelerate and stop in a wheelie' tasks. For all tasks, ICCs were above 0.95 except for the 'level propulsion forward' task, which had a lower ICC (0.49). As for the minimum and maximum 95% CIs, they were close together and high, varied from 0.88 to 1.0, except for 'level propulsion forward' (0.27-0.80). Per task analysis of the TEM index revealed task's average TEM of 0.30 for the TOWM, and 0.38 for the Wheelie test.

Table 3: **Intrarater reliability of the quality scores (*n*=20)**

Task	t1 (1st) Mean ± SD	t1 (2nd) Mean ± SD	Sig.	ICC	95% CI	TEM
TOWM						
Level Propulsion Forward 4x4	4.3 ± 0.7	4.2 ± 0.6	0.37	0.49	-.27-.80	0.55
One hand propulsion (10m)	2.8 ± 1.7	2.6 ± 1.6	0.10	0.96	.90-.98	0.57
Ascend sidewalk 10 cm	0.8 ± 1.8	0.8 ± 1.8	1.00	1.00	1.00	0
Descend sidewalk 10 cm	3.6 ± 1.7	3.7 ± 1.7	0.41	0.97	.93-.98	0.39
Ascend sidewalk run up 10 cm	2.8 ± 2.4	3.0 ± 2.5	0.07	0.99	.98-.99	0.32
Up a slope 15%	3.8 ± 1.6	4.0 ± 1.5	0.06	0.98	.95-.99	0.35
Down a slope 15%	3.5 ± 1.6	3.6 ± 1.6	0.32	0.99	.98-.99	0.16
Up a slope with a run up	1.6 ± 2.1	1.5 ± 1.9	0.08	0.99	.97-.99	0.27
Down a slope, stop in wheelie	2.1 ± 2.4	2.1 ± 2.4	1.00	1.00	1.00	0
Chair transfer stable	3.1 ± 1.8	2.9 ± 1.7	0.10	0.97	.94-.99	0.39
Total quality score TOWM	**28.7 ± 13.5**	**28.5 ± 12.7**	**0.66**	**0.99**	**.99-.99**	**1.07**
Wheelie test						
Stationary wheelie	3.4 ± 1.3	3.4 ± 1.3	1.00	0.95	.88-.98	0.27
One handed wheelie	1.2 ± 1.8	1.4 ± 2.0	0.41	0.96	.90-.98	0.35
Wheelie forward 10 m	2.9 ± 1.9	2.6 ± 1.8	0.11	0.95	.88-.98	0.67
Wheelie backward 10 m	1.9 ± 1.5	1.9 ± 1.6	0.65	0.97	.93-.98	0.27
Circle forward	2.9 ± 2.1	3.0 ± 2.1	0.48	0.97	.93-.99	0.39
Uneven surface	1.5 ± 1.8	1.1 ± 1.4	0.02*	0.96	.91-.98	0.47
Accelerate and stop in wheelie	1.7 ± 2.0	1.3 ± 1.6	0.01*	0.97	.93-.98	0.32
Backward over curb	1.4 ± 1.8	1.5 ± 1.9	0.41	0.97	.94-.99	0.27
Total quality score Wheelie test	**17.0 ± 11.9**	**16.4 ± 11.4**	**0.17**	**0.99**	**.98-.99**	**1.06**

t1 (1st) = Test occasion 1, First assessment; t1 (2nd) = Test occasion 1, second assessment done by the same rater one week after;
Sig. = Significant level; ICC = Intraclass Coefficient; 95% CI = 95% Confidence Interval;
TEM = Technical error of measurement
* Statistical significant differences

The interrater reliability

The results of the interrater reliability are presented in Table 4. No significant differences were found between the two raters based on the total quality scores of both tests, supporting hypothesis 3. The ICC associated with the interrater reliability of both the TOWM and Wheelie test total quality score was 0.99.

Interrater TEM of the TOWM quality total score was 1.23, and 1.04 for the Wheelie test, which corresponds to a relative TEM of 4.3% and 6.1% respectively.

The analysis of each task separately showed a significant difference between the two raters for the 'descend 10 cm sidewalk' task. ICCs per task varied from 0.89 to 0.99 in both tests, except to 'level propulsion forward' (0.44). Per task analysis of the TEM index revealed task's average TEM of 0.44 for the TOWM, and 0.39 for the Wheelie test.

Table 4: **Interrater reliability of the quality scores (*n*=20)**

Task	**t1 R2** **Mean ± SD**	**t1 R3** **Mean ± SD**	**Sig.**	**ICC**	**95% CI**	**TEM**
TOWM						
Level Propulsion Forward 4x4	4.3 ± 0.7	4.4 ± 0.6	0.76	0.44	-.40-.78	0.52
One hand propulsion (10m)	2.8 ± 1.7	2.6 ± 1.6	0.38	0.89	.73-.95	0.71
Ascend sidewalk 10 cm	0.8 ± 1.8	0.7 ± 1.6	0.16	0.99	.97-.99	0.22
Descend sidewalk 10 cm	3.6 ± 1.7	3.2 ± 1.7	0.03*	0.94	.87-.98	0.59
Ascend sidewalk run up 10 cm	2.8 ± 2.4	2.7 ± 2.3	0.48	0.98	.95-.99	0.45
Up a slope 15%	3.8 ± 1.6	4.0 ± 1.4	0.06	0.98	.95-.99	0.42
Down a slope 15%	3.5 ± 1.6	3.6 ± 1.6	0.32	0.99	.98-.99	0.16
Up a slope with a run up	1.6 ± 2.1	1.7 ± 2.2	0.71	0.98	.95-.99	0.42
Down a slope, stop in wheelie	2.1 ± 2.4	1.9 ± 2.2	0.32	0.96	.91-.98	0.59
Chair transfer stable	3.1 ± 1.8	3.2 ± 1.8	0.65	0.98	.94-.99	0.35
Total quality score TOWM	**28.7 ± 13.5**	**28.1 ± 12.9**	**0.15**	**0.99**	**.99-.99**	**1.23**
Wheelie test						
Stationary wheelie	3.4 ± 1.3	3.3 ± 1.4	0.74	0.93	.83-.97	0.47
One handed wheelie	1.2 ± 1.8	1.1 ± 1.7	0.58	0.96	.88-.98	0.50
Wheelie forward 10 m	2.9 ± 1.9	2.8 ± 2.0	0.48	0.97	.93-.99	0.45
Wheelie backward 10 m	1.9 ± 1.5	1.9 ± 1.7	0.65	0.97	.93-.99	0.35
Circle forward	2.9 ± 2.0	2.9 ± 2.1	0.71	0.98	.94-.99	0.42
Uneven surface	1.5 ± 1.8	1.6 ± 1.9	0.41	0.98	.94-.99	0.39
Accelerate and stop in wheelie	1.7 ± 2.0	1.6 ± 1.9	0.32	0.99	.96-.99	0.32
Backward over curb	1.4 ± 1.8	1.5 ± 1.9	0.16	0.99	.98-.99	0.22
Total quality score Wheelie test	**17.0 ± 11.9**	**16.90 ± 12.51**	**0.57**	**0.99**	**.99-.99**	**1.04**

t1 R2 = Assessment of the quality scores obtained at test occasion 1 done by Rater 2
t1 R3 = Assessment of the quality scores obtained at test occasion 1done by Rater 3
Significant level = 0.05; ICC = Intraclass Coefficient; 95%
CI = 95% Confidence Interval; TEM = Technical error of measurement
* Statistical significant differences

DISCUSSION

This study examined the test-retest, inter- and intrarater reliability of two new WM skill performance tools, designed to assess the WM of persons with SCI. In addition to two scoring systems that were used in previous tests already, the ability score and the performance time score[9,12], an anxiety score and a qualitative scale based on skill maturity criteria were introduced. The latter are unique scoring methods and as far we know, were never used before in instruments aiming to assess wheelchair skill performance. The intentions of developing these methods were first, to include the psychological impact (anxiety) on WM performance, and secondly, to break down each task of the TOWM and the Wheelie test into five skill maturity criteria, so each participant could be qualitatively assessed in detail, according to the maturity of his WM skill performance[19]. This method provides meaningful feedback to both the therapist and the client and it allows later on to use the score sheet as a teaching aid and rehabilitation guide.

Twenty-nine wheelchair users participated in the study in total. This is a rather small sample, but it is quiet similar to sample sizes used in other studies assessing the reliability of new wheelchair skill tests[6, 11-13, 15]. Despite the small sample, representation of different lesion levels and time passed since injury was a goal; therefore, it represents a wide range of spinal cord injury levels and it includes participants shortly after clinical rehabilitation next to participants who have been using a wheelchair for decades. Consequently, the result may be quite representative to the wider population of SCI who are manual wheelchair users. The one week between the two test occasions was to avoid learning and training effects during the testing period, which might have negatively influenced reliability. This seems to have been quite adequate, although anxiety scores seem to show a 'learning' trend.

Following the conclusions of the literature review[18], the use of four different scoring methods within one test, provides more detailed, comprehensive and sensitive information about the participant's WM level. In addition, a global/total score of each scale is obtained. The total score gives an impression on how proficient the participant is when performing the tasks on each subtest. Subtest scores and total score allow for comparison between or within participants.

Test – retest reliability based on total scores

According to standards suggested by Eliasziw et al.[26], the test-retest reliability ICCs values for the total ability, time, and quality scores were excellent. It indicates that both tests were able to measure WM with consistency and no learning or training effects were demonstrated.

The only significant difference between t1 and t2 was confirmed for the anxiety scores. Participants in the retest were significantly less anxious. It can be explained by the psychological habituation effect of the first test trial. Once a person is familiar with the environment, with the tasks, and he feels secured and trusts the guard, (safety person), it is only logical that his anxiety in the second trial will be reduced. To avoid this learning effect in future studies, it is advised to have one dummy session (before t1) for habituation. However, the fact that the participants were less anxious in the second test did not affect the performance scores.

Response stability indexes, found in this study, revealed that the ability and quality scales are more reliable than the time and anxiety scales. The low SEM and CV_{ME} values for the TOWM and Wheelie test total ability and quality scores represent a reasonable measurement error indicating precision and high response stability for the ability and quality scales. However, total time score showed high response variability (especially for the TOWM). It indicates that the participants may have put more emphasis on performing the task well rather than performing it fast, leading to high time variability from trial to trial. This finding is consistent with previous studies arguing the relevancy of time measurement when assessing daily wheeled mobility skills[19]. Because response stability indexes are based on the variability within the difference scores, they do not account well for the anxiety scale which had significant difference (systematic bias) between t1 and t2.

The minimal detectable change (MDC_{95}) values, found in this study, indicate that in a future intervention based on repeated measurements of the TOWM and the Wheelie test, total ability score of both tests will need to exceed about 1.5 points, and total quality scores will need to exceed about 3.5 points, in order to be confident (in 95%) that the difference is due to a real wheeled mobility ability change and not due a measurement error. Since MDC_{95} values for wheeled mobility test-retest assessment were not reported in previous wheeled mobility studies, it is recommended to establish in the future, an estimated MDC_{95} values for different range scores of the TOWM and the Wheelie test. ICC's values, found in the current study, were compared to values reported in previous three wheeled mobility tests[6, 8, 13]. The test test-retest ICC values for the TOWM and Wheelie test were 0.96 and 0.98 respectively for the total ability score and 0.99 for the quality score. These values are similar to those reported for the overall score of the Obstacle course assessment of wheelchair users performance test (OCAWUP)[6], and for the Wheelchair physical functional performance test (WC-PFP)[13], and higher than the test-retest ICC's of 0.90 reported for the Wheelchair skill test (WST 2.4)[8].

None of the previous wheeled mobility tests, published in the international literature, included reliability assessment on measurement error parameters such as response stability indexes or minimal detectable change[18]; therefore, the parameters reported in this study could not be compared with previous findings.

Test – retest reliability based on quality scores per task

The quality assessment per task showed that 'level propulsion forward' had low ICC values. This can be explained by the low variance in the scores, since all participants obtained a high score on this particular task.

The Wheelchair Skills Test (WST version 2.4) showed a success rate of 100% for level propulsion forward[8], from which it can be concluded that this task is simply too easy. However, level propulsion forward is the task most frequently tested in the available tests evaluating wheelchair skill performance[18] and was graded extremely essential WM skill in the international survey among users[27].

The current study observation may suggest omitting this task from the TOWM due to a ceiling effect. However, the sample included only post rehabilitation wheelchair users; therefore decision to omit this task should be made only after testing the TOWM with participants during their early stage of rehabilitation.

The significant differences between t1 and t2 in the quality scores of the 'wheelie forward' task may suggest a learning effect for this particular skill. To overcome this learning effect, it is recommended to have habituation session before t1.

Response stability analysis per task showed that 'One handed propulsion' of the TOWM, and 'one handed wheelie' of the Wheelie test were found have the highest response variability, pointing that it was difficult for the participants to reproduce the same results in the repeated experiment. A possible explanation may be that one handed tasks were not familiar to the participants, as they are less required in daily life situations, leading to performance variability from trial to trial.

Minimal detectable change (MDC_{95}) analysis per task indicated that for the first two tasks of the TOWM (level propulsion and one-hand propulsion), and for wheelie forward on 10m line, at least 2 points change between t1 and t2 is needed, in order to claim a real performance change, for these tasks. It should be noted that that a common characteristic of these three tasks is that the camera shooting angle is in constant change (following the participant) while in other task the camera is fixed. This may be an explanation for a higher measurement error while video assessing of these tasks. A field test "on spot" assessment analysis is recommended in order to verify if the inconsistency is indeed due to the video analysis difficulties or that the task criteria are not clear enough and need refining.

Intrarater reliability

The intrarater ICC of the total quality scores was 0.99, for both, the TOWM and the Wheelie test. This is a high value compared to intrarater reliability reported in three previous wheeled mobility tests [8,10,12].

Relative TEM of 3.7% for the intrarater assessment of the TOWM, and 6.3% for the Wheelie test were found.

There are no acceptable ranges for technical error of measurement (TEM) for neither interrater nor intrarater wheeled mobility skill assessment (unlike other domains, such as anthropometry, where the relative TEM for beginner anthropometrist for intrarater skin folds measurement is known to be 7.5% and 5% for a skillful anthropometrist)[28]. Future studies should aim to establish relative TEM acceptable ranges in wheeled mobility assessment.

Per task intrarater analysis, showed that ICC values for all tasks, except for 'level propulsion forward' were excellent. The low ICC value for 'level propulsion forward' (0.50) was a result of the small variance between participants scores (Variability among subjects' scores must be large in order to demonstrate reliability).

The significant differences that were found between the two quality measurements of the 'uneven surface' and 'accelerate and stop in a wheelie', might indicate that the skill maturity criteria in these cases were not as clearly formulated as for the other skills. "The major protection against tester bias (i.e. the observer can be influenced by his memory of the first score), is to develop grading criteria that are as objective as possible and to train the tester in the use of the instrument"[22]. On that account, it is advisable to review the quality criteria of these specific skills and to make adjustments as necessary.

Interrater reliability

Similar to the intrarater reliability, the interrater reliability value for the total quality scores, and for all tasks except 'level propulsion forward', were excellent. The interrater ICC values of both tests total quality scores (0.99) are higher than the ICC values reported to the overall scores of four previous wheeled mobility tests[6, 8, 10, 12].

The significant difference between the two raters that was found for 'descend 10 cm sidewalk', indicates the need to review the maturity criteria to maximize the reliability when qualitatively assessing this skill.

Limitations and future work

As suggested by Routhier et al[7], the procedure of quality assessment by video, which was used in this study, might be a limitation, since the examiners cannot see everything done by the wheelchair user as a result of a 2D film and restricted view produced by the video, compared to human observation of real life conditions and actions. In addition, Kirby et al.[8] agreed that scoring from a silent videotape is more challenging than doing so in person and that it might underestimate the true reliability. It is suggested that in future research, the quality assessment will be carried out on field, to allow comparison between both evaluation methods and to reassess the reliability of the quality scale.

The interrater reliability in this study was based on two raters' assessment and for the quality criteria only. It is recommended that in a future study, interrater will be assessed by 3 raters and will be tested also for the ability scores.

The time scale was found as less sensitive and the anxiety scale showed learning effect; it is recommended to reassess wheeled mobility with the TOWM and the Wheelie test following habituation session, and to perceive if response stability findings will get changed. If instability recurred, it would be suggested not to include these scales in future studies.

In the intrarater and interrater analysis, TEMs demonstrated more errors when assessing the Wheelie test tasks compared to the TOWM. This reflect not only the need of refining the quality criteria of the Wheelie test tasks, but also the necessity of technical training of evaluators on the quality assessment of the Wheelie test, in order to minimize the variability verified.

CONCLUSION

Results suggest substantial to excellent reliability of the total ability and quality scores of the TOWM and the Wheelie test, when assessing WM of manual wheelchair users with SCI. It may be considered to omit the 'level propulsion' task from the TOWM, if a "ceiling effect" will be detected also among participants during the early rehabilitation phase. The quality criteria of 'descend 10 cm sidewalk' and 'one handed propulsion' (from the TOWM), and 'wheelie forward', 'uneven surface' and 'accelerate and stop in a wheelie' (from the Wheelie test), need to be reviewed and possibly adjusted. Reducing the number of tasks may also be considered.

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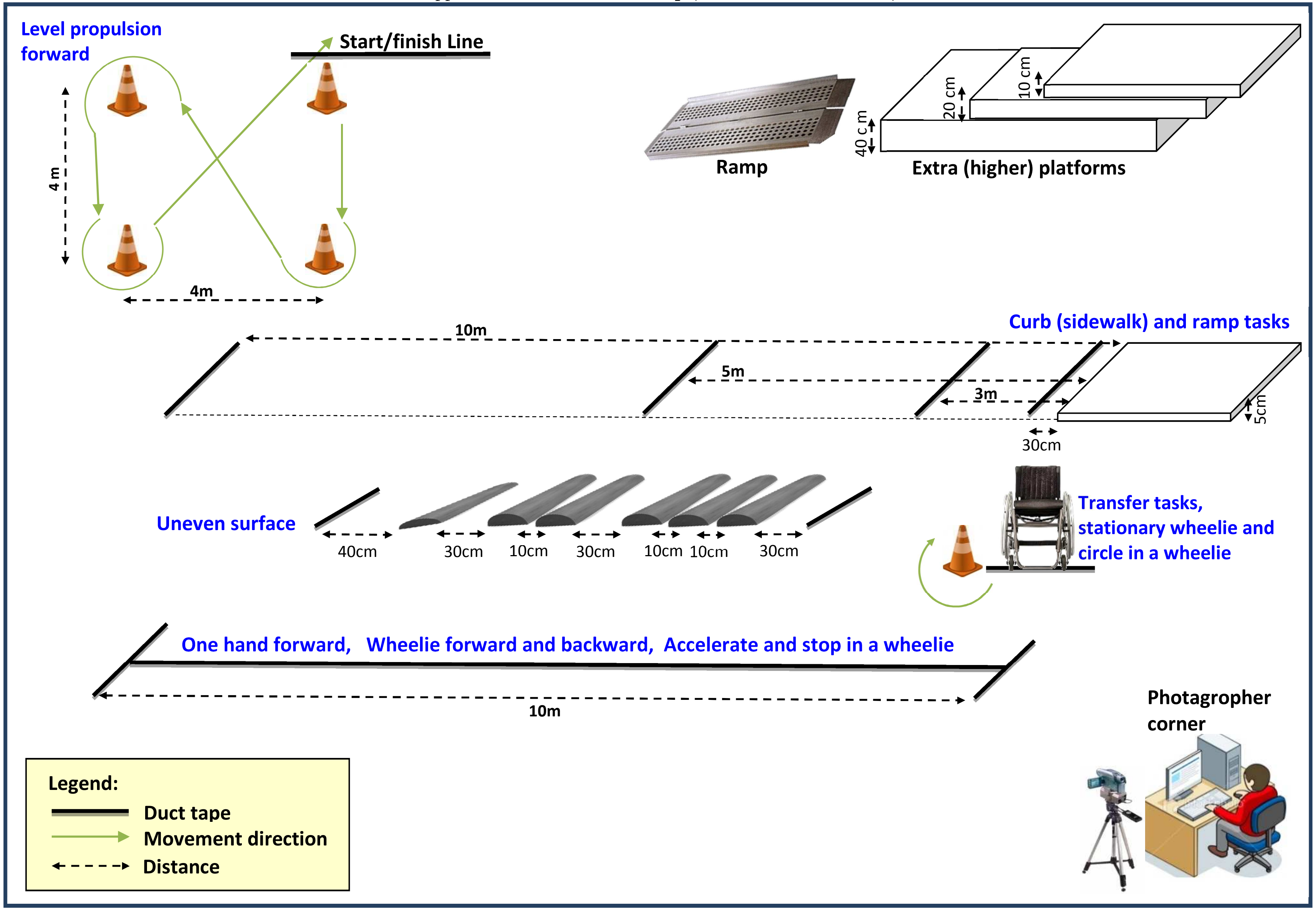
Appendix 1: **Schematic test map (TOWM & Wheelie test)**



Chapter 9

General discussion and future directions

INTRODUCTION

Skilled wheelchair use is the key to independence for a large group of people with a handicap, especially for those who will not return to walking again, such as individuals with a complete spinal cord injury. As concluded in the literature review (chapter 2), many wheelchair skills tests are applied to measure wheelchair mobility, using a large variety of skills, equipment and outcome measures, but "There is no one broadly accepted wheelchair skills test allowing comparison of study results" [1]. The same conclusion was stated by Kilkens et al. already in 2003[2], but nevertheless, another four different wheelchair skill tests were developed and presented afterwards[3-6].

The aim of the current study was to develop a "Test of Wheeled Mobility" (TOWM) for hand rim wheelchair users, based on the most prominent components of existing tests and other mobility aspects found to be most relevant for daily life as a wheelchair user.

Norms and standards are important in setting guidelines, and they provide a systematic structure for effective goal planning and assessment of the rehabilitation process. The expected functional outcomes for motor complete SCI based on neurological level, as presented in different articles and books, are expressed in terms of required assistance and equipment. In those tables, only a few aspects of mobility are considered and the skills are generally formulated giving unclear guidelines and lacking well defined wheelchair skills[7-10].

A proposed list of the minimal and maximal expected attained goals of WM skills for SCI patients, according to their lesion level, with well-defined skills, including measures of slopes, curb height and more, will allow a comparison between patients with a similar lesion level and a prediction of their maximal functionality and independency.

Not a key point of this dissertation, but yet a preliminary assumption of the investigator was that wheeled mobility of persons with a SCI gained during the acute rehabilitation process is not optimal, compared to the skills gained by those who are well-trained for years. This assumption has been supported by literature, clinical experience and subsequently in the international survey conducted as part of the current study[11]. The need to address all areas affected by the spinal cord injury during the clinical rehabilitation phase is essential if the process is targeting the learning and developing of new skills[10]. "The acute rehabilitation team has a tremendous influence on what a person knows and believes about his or her future function and life”[9]. However, in some countries, the limited length of stay in the rehabilitation center is not allowing the patient to achieve the ultimate level of WM functioning during that time. Furthermore, it seems to be a difficult task to obtain a detailed description of global pathways for functional training during the rehabilitation phase; “a systematic, worldwide accepted framework, for incorporating WM skills development into the rehabilitation process does not exist”[11] (Chapter 6).

Establishing norms and standards for WM skills performances, followed by a well-structured protocol of what, how and when to teach WM skills during and after the clinical rehabilitation phase, monitored by a standardized test of WM, are desirable goals for improving the daily functioning and quality of life of individuals with a spinal cord injury. This thesis intended to contribute in this realm.

In the next part of this chapter, some methodological considerations, practical implications, and recommendations for future research will be discussed.

Methodological considerations

Study population – international perspectives

This dissertation, starting with the development of the perceived Self-efficacy in WM scale (chapters 4 & 5), continued with the international survey among users (chapter 6), followed by the panel of experts who developed the TOWM and the Wheelie test (chapter 7), includes a representative sample of the majority population of manual wheelchair users with a SCI (in terms of lesion level, completeness, activity level, time since injury, etc.). Yet, it uniqueness and strength lies in the fact that it includes the opinions, theoretical and scientific background as well as the practical experience of a large group of people from different countries. It combines the ideas of therapists who are working in rehabilitation centers, along with coaches and trainers who work with elite-athletes; it reflects the need of people who live in developed countries and also those who live in less developed parts of the world. International perspectives were the core and the essence of this dissertation.

Relying on the strengths of existing tools and on wheelchair users’ opinions

The TOWM includes prominent components from existing tests[1]. For example, the ability score and performance time scores were adopted from the Wheelchair

Circuit[6] (but a second trial was added to allow adding a half point). In addition, the skills that were selected for the international survey among users were also derived from the existing tests. The idea to link the set of skills included in the TOWM, to architectural accessibility codes, followed the OCAWUP[4] that correlated the level of inclines to the National building Code of Canada. In order to encourage the acceptance of the TOWM worldwide, the skills were defined using the UN-norms, standards and architectural accessibility codes[12].

For most existing tests, content validity was based on the involvement of health professionals in the development of the test as well as on literature studies. A leading principal of this research was to base the TOWM on a collection of SCI athletes' opinions regarding the most essential WM skills. The opinions of wheelchair users from 18 different countries (from the 5 different continents) were considered in the process of skill selection. Furthermore, the panel of experts that worked on the development of the test included wheelchair users with a SCI, representing both genders and all SCI lesion levels who are manual wheelchair users.

Incorporating psychological aspects influencing performance

The PAD model was chosen as the theoretical framework underlying the current study[13]. It is assumed that maximizing wheeled mobility and achieving overall independence are influenced by attitudinal factors such as self-efficacy, anxiety, motivation and other variables, rather than by disability-related factors alone[14] (Chapter 5). In this dissertation, a new valid and reliable perceived Self-Efficacy in WM scale was developed and presented (chapters 4 & 5)[15-16]. Besides self-efficacy, positive correlation was found between the TOWM and the Wheelie test's *anxiety scores* (chapter 7), supporting the assumption of how psychological variables actually affect WM performance. As far as we know, this is the first WM skill test that includes the aspect of anxiety.

The TOWM

In the critical evaluation of “strengths and weaknesses of existing wheelchair skills tests” (chapter 2), a test was considered "stronger" when it met more of the following aspects: (a) Quantity data are presented allowing comparison with other tests or previous trails; (b) Quality analysis (on field and/or video recorded performance, analyzed by experts) enable trainers (PT, PE and peers models) to improve their teaching skills and also for the enhancement of the sensitivity of the test; (c) Feasibility – the duration of the test is no longer than 30 minutes; (d) Expressed final test score; (e) Test everyday wheeled mobility skills rather than "lab" examinations: using skills that are needed in everyday life, using their own manual wheelchair; (f) WM test for persons with a SCI; (g) Assessing the differences in level of wheelchair skills performances of SCI, sensitively and precisely.

Strengths of the TOWM

a. The TOWM scores allow comparison between different participants as well as comparison to previous test' trials done by the same person.
b. The quality score, based on performance component criteria, gives a meaningful feedback to the trainers about the mistake made and how to correct in next trials.
c. The test is feasible in terms of cost, settings and duration. For example, average total testing time is 24.7±5.93 min. (less than 30 minutes).
d. Each of the TOWM four scales is expressed by a final score (e.g. total ability score, total quality score, total time score and total anxiety score).
e. The TOWM is relevant to daily life situations as it is conducted in a community setting and the participants are using their own wheelchair.
f. The TOWM was developed to specifically target individuals with a SCI.
g. The psychometric properties of the TOWM partially confirmed that the assessment of WM is sensitive and precise.

Weaknesses of the TOWM

a. An overall score has not been developed yet.
b. The quality criteria of 'descend 10 cm sidewalk' need to be reviewed as it was found to be less consistent.
c. The 'Level propulsion' task showed a "ceiling effect".
d. Anxiety measurement was impacted by a learning effect on the skill performance.
e. In order to rate all 4 scores, a minimum of two trained examiners are required.
f. The TOWM and the Wheelie test were not evaluated with patients during inpatient stay at the hospital, neither with females.
g. No data regarding sensitivity to change over time are available yet (i.e. longitudinal study testing the same participants at different times: during rehabilitation, at the time of discharge and after rehabilitation).

The Wheelie test

The strengths and the weaknesses of the Wheelie test are quiet similar to those of the TOWM, but there are few major differences between the two; first, the duration of the Wheelie test is much shorter (12.6 ±5.08min.). Also, less expensive and simpler equipment is required to conduct the Wheelie test. A weakness of this test is that there could be a risk of tipping backwards in certain tasks, which could make the test a bit challenging for the participants. Therefore, the test supervisor is responsible to avoid any risks.

Reflection on methodological procedures and statistical analyses applied in this research project

In this dissertation, new instruments for the evaluation of WM were developed and tested. In the development of new assessment tools, several methodological and statistical issues are need to be addressed before it would be possible to indicate that these tools are valid, reliable, feasible and merits international application as to monitor the development of WM skills from the start of rehabilitation after SCI, discharge of the acute rehabilitation phase and follow up.

This section will critically review decision-making and statistical procedures of the various studies conducted within this project.

In the first study (chapter 2), a systematic literature review was carried out. Following the publication of this study, Dr. Lee Kirby wrote a published letter to the editor of *Clinical Rehabilitation*[17], with a positive and negative audit. His major objection was toward the idea of the development of one standardized WM test. Dr. Kirby stated in his conclusion that “it seems to me to be quite desirable to have a battery of instruments from which to choose for different purposes and settings. The authors have gone a long way toward providing the sort of information that clinicians and researchers need when selecting an instrument that meets their needs”.

In the second study, (chapter 3), an assessment of differences in WM levels of persons with a SCI between discharge from inpatient rehabilitation (t1) and 1 year after discharge (t2) was conducted based on the Dutch prospective longitudinal study, using an existing data from the "Wheelchair circuit" (Kilkens et al., 2004)[6]. In addition to the study limitations as presented in the article, the statistical procedures undertaken should be critically reviewed; when the outcome measures are rating scales, methods appropriate for ordinal data are recommended, such as nonparametric methods for direct group comparisons in treatment evaluations. The rational to perform multilevel regression analyses was based on two reasons: first, differences between rehabilitation centers were detected. Secondly, it was the only way we could compare our study result with the previous study done by Kilkens et al[6], (by running the same statistical analysis). However, modeling the ability score as a continuous outcome measure in a linear regression model is questionable since the distribution of the current study score was highly skewed with most individuals having their scores close to the upper limit. As a sensitivity analysis, we considered using a mixed ordinal regression and we ran additional regression analyses with the ability score as a count variable by mean of a Poisson model. The result was almost the same but with two differences: completeness was significantly related to the ability score and wheelchair satisfaction was not related anymore.

In studies 3 and 4 (chapters 4 and 5), the perceived self-efficacy in wheeled mobility scale (SEWM) was developed and assessed. The reason for choosing Likert scale based on 10 items was to formulate the SEWM in the same construct as the familiar Generalized Self-efficacy scale. However, 75% of the participants had reached the maximal score of 40 which demonstrated a clear ceiling effect. One explanation for that could be the relatively active sample, which included athletes and young people who were integrated in a community based recreational activities. But maybe the design chosen for the scale was not optimal and if perceived self-efficacy in wheeled mobility was tested with a Guttman scale design, for example, where the agreement with higher-level responses assumes agreement will all lower-level responses, then the SEWM could be reduced in number of items and ceiling effect would have been avoided. Another limitation of our study is that a test-retest reliability analysis was not performed. In October 2012, a test-retest analysis of the SEWM will be assessed on individuals with SCI upon discharge from rehabilitation centers, and on inactive individuals with tetraplegia. The result of the future study will be compared with the current study result.

In study 5, (chapter 6), a list of the most necessary wheeled mobility skills for daily life of manual wheelchair users was established. Our goal was to find out which of the presented skills will be considered as "very essential' and which skills will not (categorical sorting). We were less emphasizing on the order of the skills. One of the arguments against survey method as we conducted is that "studies using surveys and questionnaires often use categories that the investigator imposes on the responses"[18]. It could be that if a ranking method as Q-sort technique was chosen, it would have provided a better reflection on the necessity of each WM skills, since such method emphases on determining the relative ranking of the skills by the participants, and in deriving cluster of skills that were displayed in a similar preference ordering. However, sorting procedure is complex and unfamiliar to the lay public; it requires administration in a face-to-face interview setting[19] (i.e. in Q methodology aiming to WM skills sorting, it is preferably to present the skills in statements on cards). In our study, we were aiming the survey for an international group of wheelchair users with a SCI, and we had to find a simple and fast method to minimalize athlete's disturbance during the Paralympic games.

Another limitation of this study is that the presented skills were pre-selected based on literature and expert's opinions. It could be that athletes who participated in this study would suggest additional skills. At the last part of the survey, the participants were asked to share comments and ideas concerning the topic of wheeled mobility; nearly 40 people filled-in the open question part and we obtained very interesting information concerning different aspects of wheeled mobility. As an example, from these answers we found out that the athletes from Greece followed a peer-learning structured wheeled mobility rehabilitation program in Sweden. Another mentioned aspect was the "blaming" of the first wheelchair. Some people claimed that their first wheelchair did not fit their needs and was an obstructive factor for the development of wheeled mobility skills. Other comments were concerning the "luck" factor meaning that training wheeled mobility skills during rehabilitation was related to the interests and knowledge of the physiotherapist. These statements are well worth a qualitative analysis and would probably suitable the most for a social sciences study. Regarding additional skills, two athletes suggested including climbing stairs task and one athlete thought that the wheeling forward task may be too easy.

In study 6 and 7 (chapters 7 and 8), The TOWM and the Wheelie test were developed and evaluated for their feasibility, validity and reliability. Due to journal's rules allowing limited word number, it was impossible to fully describe the 2 years development process of both tests. This is why, for instance, equipment and materials were not described within the text and the readers were directed to the on-line test protocol. Also the development of the Wheelie test was not described in the article. The idea to develop the Wheelie test was raised during the tryout session. We realized that skilled wheelchair users might not be sensitively differ unless more challenging tasks would be tested. It was also noticed that those who were able to control their wheelie, were able to perform the TOWM tasks with much effortlessness. However, in the current study, only 1 participant was 'novice' WM-users (less than 2 months post discharge from rehabilitation). Therefore it is unknown yet whether the TOWM and the Wheelie test are feasible to apply at the start of rehabilitation. It would be logical to expect in early rehabilitation a bottom effect, mainly for the Wheelie test. The answer for that is assumed to be found in our future study. If that would be the case, it might be suggested to apply the Wheelie test only in post-rehabilitation wheeled mobility interventions programs and to adapt the TOWM tasks for novice wheelchair users. (It is important to clarify that few tasks of the TOWM require performing wheelie as well, e.g. descending sidewalk and high slope ramp).

Reflections on the TOWM and Wheelie test measurement scales

The performance time score and the ability score were selected based on scales that were used in existing wheeled mobility tests. Following the current study result, it is suggested not to test *performance time* in future studies.

The idea to design the *quality scale* on “performance criteria” should be also explained. The researcher had years of experience assessing children with cerebral palsy with the “test of gross motor development”, also known as the Ulrich test[20]. In Ulrich test, each gross motor skill includes three or four behavioral components that are presented as performance criteria and represent a mature pattern of the skills. Because the TOWM and the Wheelie test are aimed for clinical applications, this scoring method offers a meaningful feedback for therapists and trainers.

In our study, the quality scores were videos assessed by two physiotherapists, but the target goal is to refine and reduce the criteria, in order to run a qualitative field assessment as in the Ulrich test. The instructions for the TOWM and Wheelie test quality scoring method are as following (copied from the test protocol):

1. Require the participant to perform 1 trial for video analysis, or 3 trials for field analysis, of each WM skill
2. Observe the participant performing the skill and concentrate on the performance criteria
3. Mark a ✓ in the appropriate box in the correct assessment column. Where a participant performs a component correctly, he receives 1 point.
4. The total quality score is the sum of the tasks points.
5. Give a quality score only for the tasks where the participant receives ability score (when he succeeds the task).

In principle, the TOWM and Wheelie test administrators should have a basic level of knowledge of wheeled mobility, but the performance criteria can also be used by university teachers to train and teach physical therapy students how to assess wheeled mobility.

The examiners in the current study were trained by analyzing videos that were not included in the reliability statistical analysis. Both agreed that after three assessments, they could remember most of the criteria by heart. Following their inter-intra reliability assessment, the two raters were asked to share their input regarding the clarity and length of the different tasks criteria. Their subjective report, matched the inconsistency detected for the same four tasks as revealed in the reliability analysis result (chapter 8).

The idea to include in the test the *anxiety scale* was raised during the tryout session; it was obvious that whoever had feared, either approached tentatively or chose not to try to execute the task at all. This is how the Anxiety visual analog scale was added to the test protocol. During the TOWM and the Wheelie test assessment, the instruction given to the examinee was to indicate how anxious he was in the context of hurting himself and not of failing the task. As was exposed in the test-retest analysis, anxiety in the retest was reduced assuming as a result of habituation effect. In future studies it is advised to have a training session prior to the assessment, in order to control this effect.

In the validity study (chapter 7), the ability, time, quality and anxiety scores were compared between the TOWM and the Wheelie test, however interrelationships of the four scores within a test were not informed to observe the way these scores are interrelated. To further investigate the discriminative ability of the different scales, correlations should be performed between the quantitative and qualitative data (between the ability and quality scores mainly), to determine if either type of data show greater discriminative ability.

Reflections on the TOWM and the Wheelie test validity testing

Since no golden standard for wheeled mobility is available, it was impossible to establish tests validity by comparing our findings to the norms. This is obviously a limitation of the current study. In previous studies aimed to assess new wheeled mobility test, the validity was determined by correlating the test result with questionnaires, mainly with the 5-items motor scores of the Functional Independence Measure[21] (FIM) (p.34, table 3). None of the previous studies were testing validity by correlating the result with “actual performance based” tool. It is questionable weather correlating two new tests is an acceptable method to determine test validity. The chosen validity type in our study was “Convergent validity”, defined as the degree to which scores on a particular test correlate with, or are related to, scores on another test that is designed to assess the same construct. High correlations between the test scores would be evidence of a convergent validity[22].

The construct validity analysis performed in the current study requires an explanation why certain variables included while others were not. In the original study, construct validity was assessed by testing whether both test four scales total scores were significantly related to physical activity level (tested with the 'Physical Activity scale for Individuals with Physical Disabilities PASIPD[23]), age, lesion level, body mass index (BMI), time since injury, anxiety (by correlating the ability, quality and time scores with the anxiety scores), and sport participation. Reporting the complete set of the tested variables resulted in a very long article which significantly exceeded journal’s permitted article length. Therefore, it was decided to split the study into two articles and only the first article was published in this book.

Construct validity findings, based on variables that were not presented in chapter 7 (in a brief glance): the TOWM and the Wheelie test scores showed fair to moderate correlation with physical activity level (PASIPD). The strongest correlation found between the TOWM quality scores and PASIPD (r=0.42). Anxiety scores showed fair to moderate correlation with both test’s scores (e.g. TOWM total ability scores and anxiety r=-0.38, TOWM quality scores and anxiety r=-0.44; the correlation is negative meaning that lower values of anxiety go with higher WM abilities). Both tests time scores showed fair correlations with age, (e.g. TOWM time score and age *r*=-0.32). Significant differences between participants with high paraplegia, low paraplegia and tetraplegia were found only for the Wheelie test time scores. No correlations were found between the TOWM and the Wheelie test four scales total scores and body mass index (BMI).

Another important critical aspect concerning the psychometric evaluation of the TOWM and the Wheelie test is that it has been conducted within the framework of classical test theory, comparable to the psychometric evaluation methods used in the development process of previous wheeled mobility tests. Over the last years however, there has been a growing awareness in the health and psychological sciences of modern test theory approaches, such as those based on the Rasch measurement model[24]. Rasch analysis allows a detailed investigation of many aspects of a scale including the response format, the fit of individual items and persons, dimensionality, targeting, and the detection of item bias. Rasch analysis identified a hierarchical ordering of items in motor performance difficulty[25]. Testing for differential item functioning is particularly important as it allows researchers and clinicians to ensure that items function uniformly across age, gender or, for example, different scale administration methods, at all difficulty levels.

In continues evaluation study, aiming to refine and farther support the psychometric properties of both tests, Rasch analysis should be used in order to: a) determine TOWM and Wheelie test item's uni-dimensionality; b) reevaluate and when possible omitting items (tasks); and c) to allow reducing the number of quality criteria per task.

Rasch analysis assists in determining item's uni-dimensionality. Results of wheeled mobility testing need to reflect the wheeled mobility abilities only rather than any external limitation (e.g. wheelchair dimensions/wheels size) or physiological variables (strength, power output) effecting wheeled mobility skill performance. If both tests scale will confirme uni-dimensionality, differences between patient scores would accurately reflect different levels of wheeled mobility.

Rasch analysis assigns an 'item estimate' to each item. This value reflects the relative difficulty of each high-level item in relation to the other items. Where several items clusters (i.e. they have similar item difficulty estimates), it enables to exclude redundant items. Task from the TOWM and the Wheelie test, as well as performance criteria from the quality scale, will be excluded in accordance with predetermined criteria, e.g. excluding item with a larger standard error of parameter (reflects the reliability of the item), or when clustered items show similar standard error of parameter estimates, the item that is more practicable will retained. Items should be assessed also for practicability by considering the testing time, equipment and location required to test each item.

Reflections on the TOWM and the Wheelie test responsiveness

Responsiveness refers to the ability of a measure to detect clinically meaningful change over time, and provides a means for determining if an individual's score changes are related to true recovery, or to natural variation in repeated performances. Scale responsiveness is an important concept for clinicians in this time of evidence-based practice, and understanding and interpreting the responsiveness of a scale enables clinicians to discriminate true change from measurement error[25].

Multiple methods have been conducted for investigating responsiveness of both tests (chapter 8), including analysis of measures related to measurement errors, e.g. technical error of measurement (TEM), standard error of measurement (SEM), method error (ME) and minimal detectable difference (MDC_{95}).

Testing the minimum clinical important difference (MCID) was also considered, to put forth as a measure for the critical threshold needed to achieve treatment effectiveness. By this measure, treatment effects reaching the MCID threshold value imply clinical significance and justification for implementation into clinical practice[26].

The term MCID was first described by Jaeschke et al.[26]. Their argument was that although statistically significant changes often occurred during use of instruments that measured change after intervention, in some cases the significant change had little clinical significance. Thus, their operational definition of a minimal clinically important difference was "The smallest difference in score in the domain of interest which *patients* perceive as beneficial and which would mandate, in the absence of troublesome side effects and excessive cost, a change in the patient's *management*".

Several reasons had led us not to include MCID analysis in this study; for example, MCID demands a patient report of outcome. Since no intervention was carried out, the participants in our study were not able to report on changes from initial baseline of their wheeled mobility abilities. Another reason to reject this evaluation was the problems associated with the calculations of MCID, as reported in the literature[27]; In essence, an MCID is required to function as a measure of responsiveness of a given instrument. However, “the responsiveness is often less reflective of the property of the instrument itself and more reflective of the intervention used during the testing”[28]. Furthermore, a tool such as a global rating of change (GRoC), which is typically used as the anchor measure, may lack internal reliability and may demonstrate variability in outcome, even if the instrument being used is stable and valid[29].

Practical implications

The SEWM (chapters 4 & 5), after testing it with more heterogeneous group, following test-retest reliability analysis, may find future applications in measuring self-efficacy beliefs in wheelchair skills performances of SCI. It can be applied in structured enhancement WM programs and also in assessing progress in WM levels in occasional as well as regular activity for people with SCI.

For clinical practice, it is recommended to integrate the sorted list of the most essential WM skills (chapter 6) into wheelchair training programs. Since these skills were considered to be the most important for participation in daily life, early training of these skills will probably result in a faster re-integration into social and professional activities. In addition, this list could be the base for establishing a concrete and if possible, a global guideline for enhancing, teaching, and assessing WM skills during clinical rehabilitation of persons with a SCI.

The TOWM and the Wheelie test protocols and equipment might also be used in training programs and the quality assessment score sheet can be a useful tool in guiding the wheelchair users into a more mature skill performance. In addition, it may be possible to use the TOWM and the Wheelie test anxiety scores to predict individuals with greater difficulty to cope with daily life challenges following SCI.

The ability to master a wheelie (balancing on the rear wheels) is related with functional wheeled-mobility skills. Training wheelie skills might be an indirect form of training functional wheelchair skills that will also increase confidence and perceived self-efficacy.

The strong correlation found between sports participation and wheeled mobility (chapters 5 & 7) suggests that participating in sports might result in a better functional outcome in terms of wheeled mobility skills performance. Although this requires further study, it is advised for clinicians to encourage their patients to join dynamic wheelchair sport activities in order to enhance WM skill's development.

Recommendations for the TOWM and Wheelie test future research

In addition to the previous mentioned methodological aspects and recommendations, the refined version of the TOWM and the Wheelie test should be retested with a larger and more heterogenic sample, including SCI patients – males and females – during their rehabilitation phase, as well as with sedentary individuals with tetraplegia. The quality scale should be tested also during an actual field test (on spot) and not solely by video analysis. The refined version of the both tests should also be used to assess the effectiveness of intervention programs in a randomized controlled trial. Repeated use of the TOWM in future studies may aid to derive norms and standards for wheeled mobility skill performance according to lesion level.

It is also suggested to test if, by teaching, training and assessing wheelchair users to master a wheelie (based on the Wheelie test's protocol), the performance of the TOWM skills will also improve substantially. A positive result, may suggest that the shorter and more economical Wheelie test may serve as an alternative to the TOWM. This however requires additional studies as mentioned before.

As final words, it is a great hope that researchers and clinicians worldwide will endorse one wheeled mobility assessment tool. A universal acceptance of one test will allow the establishment of norms and standards for wheeled mobility skills performances.

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ENGLISH SUMMARY

Manual wheelchair mobility is important for a large number of people, especially for those who will not return to walking again, as individuals with a complete spinal cord injury. To function independently, manual wheelchair users must possess a variety of wheelchair skills, in order to deal with the physical barriers they will encounter in various situations in daily life.

In this context, *wheelchair skill performance* is defined as: “The ability to move around and overcome obstacles encountered when carrying out daily activities or social roles in a self-propelled wheelchair" (Routhier et al., 2003). *Wheeled mobility* (WM) is defined as: “Moving around using equipment: moving the whole body from place to place, on any surface or space, by using specific devices designed to facilitate moving or create other ways of moving around, such as moving down the street in a wheelchair or a walker" (ICF WHO 2001).

WM skills learned during the rehabilitation period should reflect the daily activities and needs of the specific patient. They should maximize the patient’s functional capacity and minimize the dependence on others. Therapists should gain more knowledge and search for ways to improve a person’s wheelchair skill performance and by this, to promote participation in community activities and social roles. Furthermore, therapists should have a valid, reliable and sensitive measuring tool at their disposal, in order to objectively and systematically assess their patient's level of WM performances, before, during and after interventions.

Functional outcomes after SCI vary from person to person (Haisma et al., 2007), depending on many factors: the level and completeness of the injury, neurologic recovery, associated complications, the amount of rehabilitation training, age, body size, weight, family support and financial status. It is assumed that maximizing WM and overall independency is also influenced by attitudinal factors like self-efficacy rather than just disability-related factors (Nosek et al., 1995). Therefore, when teaching and assessing wheelchair skills performances, the psychological aspects (e.g. self-efficacy, anxiety, motivation), should also be considered.

A "WM skills test" consists of different tasks to be performed by the candidate under standardized conditions. A validated and reliable wheelchair skills test is necessary as a guiding instrument in the rehabilitation process of people with SCI and those with lower limb impairments. Measurement of mobility can assist

in diagnosis, choice of the appropriate therapy, and evaluation of a patient progress and the effects of treatment (Bussmann et al., 1998). Many tests are applied to measure wheelchair skill performance using different tasks and outcome measures. This makes it difficult to compare study results. Furthermore, a standardized and accepted WM skills test could be used to develop standards of wheelchair skills performance for individuals with different levels of impairment. Such common WM skills test was not available to date (Kilkens et al., 2003. Fliess-Douer et al., 2010).

This study aimed to develop a standardized test of wheeled mobility (TOWM) for hand rim wheelchair users with a SCI, in order to promote the establishment of norms and standards for WM skill performances. The main research question was: which skills, scale and equipment should comprise a wheelchair skills test that is valid, sensitive and reliable, aimed for fast and easy screening, differentiating between a wide range of performance levels of hand-rim wheelchair users with a SCI?

In the first study (chapter 2), a systematic literature review was carried out. The main objective of this review was to systematically review, document, analyze and critically appraise the performance-based wheelchair skills tests for manual wheelchair users, especially those with a spinal cord injury, currently available in the international literature. An added value of this study was that it facilitated a selection of the most suitable components from the existing wheelchair skills tests in order to develop a standardized test.

To test the preliminary assumption about the level of WM gained during the acute rehabilitation phase, an assessment of differences in WM levels of persons with a SCI between discharge from inpatient rehabilitation (t1) and 1 year after discharge (t2) was conducted. This was based on the Dutch prospective longitudinal study, using an existing data from the "Wheelchair circuit" (Kilkens et al., 2004). An attempt was made also to determine the personal and environmental factors that contribute the most to changes in wheelchair skill performances (chapter 3). Results showed that the scores of the Wheelchair Circuit were stable over the year after discharge from the rehabilitation center. Change in wheelchair skills performance in the year after discharge was not different between groups with different personal or lesion characteristics, while perceived self-efficacy was positively related to the course of wheelchair skill performance over time. The main conclusion of this study was that wheelchair skill performance, measured by means of the Wheelchair Circuit test, stabilizes during the first year after discharge from inpatient rehabilitation and perceived self-efficacy had a positive impact on changes in wheelchair skill performance during that time. The Wheelchair Circuit was found less suitable for testing wheelchair skill performances in the post-acute rehabilitation phase of people with SCI due to a ceiling effect of the ability score (most of the participants already reached the top level at the end of the rehabilitation program and could not further improve).

The next study (chapter 4) aimed to develop a valid and reliable scale assessing perceived Self-Efficacy in Wheeled Mobility (SEWM). This scale was developed for two main purposes: (a) recruiting the most competent people with SCI (in terms of WM perceptions) in order to create a panel of experts advising and sharing their knowledge with the research team when developing the new test of WM; and (b) to provide evidence for the validity of the test of WM developed in this study, by correlating both tests results. Furthermore, such scale can find wide applicability in clinical and community settings in wheeled mobility focused interventions for people with SCI. No self-efficacy in wheeled mobility scale was found in the international literature. The main results of this study (n=47, only paraplegic) showed high internal consistency of the SEWM but two items showed lower correlations with the total score. The conclusion of this study was that SEWM seems a reliable and valid instrument in manual wheelchair users with a SCI, but items 8 and 9 were advised to be rephrased, and a larger sample (including individuals with tetraplegia) was suggested to support the statistical properties of the scale.

An opportunity was given during the Beijing Paralympic games 2008, to support the preliminary psychometric findings of the SEWM scale, after rephrasing item 8 and 9 (chapter 5). A comparison of self-efficacy perceptions between athletes with a SCI competing in dynamic wheelchair sports to athletes who participate in static and non-wheelchair sports was carried out. Results confirmed high internal consistency and construct validity of the SEWM, and athlete's subgroups investigation showed that athletes with tetraplegia perceived significantly lower WM levels than those with paraplegia. Furthermore, athletes who participate in dynamic team wheelchair sports perceived the highest level of WM while athletes competing in static wheelchair sports perceived the lowest WM levels.

A survey among elite athletes with SCI was also conducted in Beijing Paralympic games, aiming to sort out the most essential wheeled mobility skills for daily life of manual wheelchair users, in order to incorporate those skills in the newly developed test of wheeled mobility (chapter 6).

Aside the sorted list of skills, survey findings demonstrated that nearly half of the participants have learned the most essential WM skills after clinical rehabilitation in a community setting.

Having in hands the critical literature review (chapter 2), the SEWM scale (chapter 4 & 5) and the sorted list of the most essential WM skills for daily life (chapter 6) "an expert team" (including wheelchair users representing all level of SCI as well as physiotherapists and academic professionals) was composed in order to develop the Test of Wheeled Mobility (TOWM). In addition, an idea was raised to develop also a short Wheelie test based on the assumption that mastering wheelie would result in a better wheelchair skill functioning.

The process of test development was iterative, with repeated reviews, try-outs and comments by the panel of experts. The TOWM and the short Wheelie test were evaluated for their feasibility, validity (chapter 7) and reliability (chapter 8). Both tests were found to be feasible, valid and reliable when assessing wheeled mobility of manual wheelchair users with SCI[1].

In the last part of this dissertation (chapter 9), some methodological considerations, practical implications, and recommendations for future research were discussed. The main suggestion was that, after rephrasing one task's quality criteria and considering omitting the 'Level propulsion' task, to use the TOWM in a larger sample, including SCI patients during their rehabilitation phase, as well as assessing the effectiveness of intervention programs by using the TOWM.

As a final point, it was advised to test if, by teaching, training and assessing wheelchair users to master a wheelie (based on the Wheelie test's protocol), the performance of the TOWM skills will get improved substantially. A positive result, may suggest that the shorter and more economical Wheelie test may serve as an alternative to the TOWM.

To conclude, the investigator expressed her hope that the final version of the TOWM and the short Wheelie test will be adopted by the rehabilitation community worldwide, and will be applied regularly, in order to derive norms and standards for wheeled mobility according to lesion level.

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[1]The protocols of the TOWM and the Wheelie test, the SWEM in different languages and the sorted list of the most essential WM skills can be freely obtain at: www.scionn.nl/inhoudp28.htm

SAMENVATTING

Manuele rolstoelmobiliteit is een belangrijke vaardigheid voor vele personen die niet meer in staat zijn om te stappen zoals personen met een volledige dwarslaesie. Om onafhankelijk te kunnen functioneren, moeten manuele rolstoelgebruikers een aantal vaardigheden beheersen om de fysieke barrières van het dagelijkse leven te kunnen overwinnen.

In deze context kan rolstoelvaardigheid gedefinieerd worden als "de mogelijkheid om zich voort te bewegen en obstakels te overwinnen in een manueel aangedreven rolstoel tijdens het uitvoeren van dagelijkse activiteiten of van activiteiten verbonden aan sociale rollen" (Routhier et al., 2003). Rolstoelmobiliteit (RM) is gedefinieerd als "Het zich voortbewegen door gebruik te maken van materiaal: het voortbewegen van het lichaam van de ene plaats naar de andere, op om het even welke oppervlakte of door een ruimte, en dit door gebruik te maken van apparaten ontworpen voor het faciliteren van het voortbewegen of door andere methodes aan te wenden om zich voort te bewegen, bijvoorbeeld het zich voortbewegen door middel van een rolstoel of een looprek" (ICF WHO 2001).

De rolstoelmobiliteitsvaardigheden die geleerd worden tijdens de revalidatieperiode zouden de dagelijkse activiteiten en specifieke noden van een patiënt moeten weerspiegelen. Ze moeten de patiënt zijn functionele capaciteit maximaliseren en zijn afhankelijkheid van anderen minimaliseren. Therapeuten zoeken hierbij naar manieren om de rolstoelvaardigheden van een patiënt te verbeteren en zo onrechtstreeks de participatie in maatschappelijke activiteiten en sociale rollen te verbeteren. Daarnaast zouden therapeuten moeten kunnen beschikken over een valide, betrouwbaar en gevoelig meetinstrument om objectief en systematisch de rolstoelvaardigheid van een persoon te meten, zowel voor, tijdens als na een behandeling.

De functionele gevolgen na een dwarslaesie variëren van persoon tot persoon (Haisma et al., 2007), en zijn afhankelijk van vele factoren: de hoogte en de volledigheid van het letsel, het neurologisch herstel, de eventuele complicaties, de hoeveelheid revalidatietraining, de leeftijd, de lichaamsgrootte en het gewicht, de gezinsondersteuning en de financiële status. Verondersteld wordt dat rolstoelmobiliteit en onafhankelijkheid, naast ziektegerelateerde factoren, ook beïnvloedt worden door meer mentaliteitsgerelateerde factoren zoals het geloof in eigen kunnen (Nosek et al., 1995). Daarom is het ook belangrijk om rekening te houden met psychologische factoren, zoals angst, motivatie en geloof in eigen kunnen, wanneer men rolstoelvaardigheden aanleert en beoordeelt.

Een "RM vaardigheidstest" bestaat uit een reeks taken die op een gestandaardiseerde manier moeten uitgevoerd worden. Een valide en betrouwbare rolstoelvaardigheidstest kan een belangrijk hulpmiddel zijn in het revalidatieproces van personen met een dwarslaesie en andere aandoeningen van de onderste ledematen. Het meten van deze vaardigheid kan helpen bij het stellen van een diagnose, bij de keuze van geschikte interventies en bij het evalueren van de vooruitgang van een patiënt en de resultaten van een behandeling (Bussmann et al., 1998). In het verleden werd er gebruik gemaakt van een grote verscheidenheid aan testmethoden om rolstoelvaardigheid te meten. Het grote verschil in taken en metingen van het resultaat van de uitvoering, maakt het echter moeilijk om de verschillende studies te vergelijken. Een gestandaardiseerde en door iedereen aanvaarde rolstoelvaardigheidstest zou gebruikt kunnen worden om normwaarden te kunnen ontwikkelen voor personen met verschillende vormen van beperkingen. Een dergelijke gemeenschappelijke rolstoelvaardigheidstest is tot op vandaag niet beschikbaar (Kilkens et al., 2003. Fliess-Douer et al., 2010).

Het doel van deze studie was om een rolstoelmobiliteitstest (TOWM) te ontwikkelen voor manuele rolstoelgebruikers, om het opmaken van normwaarden mogelijk te maken. De voornaamste onderzoeksvraag was: Welke vaardigheden, welke meetschaal en welk materiaal zijn nodig om een rolstoelvaardigheidstest te ontwikkelen die valide, gevoelig en betrouwbaar een snelle en eenvoudige screening toelaat en kan differentiëren tussen de uiteenlopende prestatieniveaus van de verschillende manuele rolstoelgebruikers met een dwarslaesie.

In een eerste studie (hoofdstuk 2) werd een systematisch literatuuronderzoek uitgevoerd. Het hoofddoel van deze studie was om systematisch de bestaande rolstoelvaardigheidstesten voor manuele rolstoelgebruikers, in het bijzonder voor personen met een dwarslaesie, te documenteren, te analyseren en kritisch te beoordelen. De resultaten van deze studie lieten ook toe om de meest geschikte componenten van de bestaande testprotocols te selecteren en in te test te integreren.

Om het vermoeden van een verbetering van het niveau van rolstoelmobiliteit tijdens de acute revalidatiefase te testen, werden de verschillen in rolstoelvaardigheid geëvalueerd tussen de tijdspanne vanaf ontslag uit het revalidatiecentrum (t1) en 1 jaar na het ontslag (t2), gebaseerd op de data van een Nederlandse longitudinale studie, gebruik makend van de data van de "Wheelchair Circuit"-test (Kilkens et al., 2004) en het Nederlandse "Umbrella project". Er werd hierbij ook geprobeerd om de persoonlijke en omgevingsfactoren te bepalen die de meeste invloed hebben op de veranderingen in de prestatie van rolstoelvaardigheid (hoofdstuk 3). De resultaten toonden dat de scores van het "Wheelchair circuit" stabiel bleven in het jaar volgend op het ontslag van het revalidatiecentrum. Verandering in de prestatie van rolstoelvaardigheid een jaar na het ontslag bleek ook niet verschillend te zijn tussen groepen met verschillende laesiehoogte en persoonlijke karakteristieken. Enkel het geloof in eigen kunnen bleek positief gerelateerd te zijn aan de prestatie over deze tijdspanne. Het voornaamste besluit uit de resultaten van deze studie is dat de prestatie in rolstoelvaardigheid, gemeten door het "Weelchair circuit", zich stabiliseert gedurende het eerste jaar na het ontslag uit een revalidatiecentrum en dat het geloof in eigen kunnen gedurende die periode een positieve invloed heeft op veranderingen in rolstoelvaardigheid. De test "Wheelchair Circuit" bleek echter minder geschikt te zijn voor het testen van rolstoelvaardigheden in de postacute fase bij personen met een dwarslaesie omwille van een plafondeffect van de bekwaamheidsscore. De meeste deelnemers bereikten immers het topniveau reeds voor het einde van het revalidatieprogramma en konden daarom niet meer verbeteren op de test.

De tweede studie (hoofdstuk 4) had als doel om een valide en betrouwbare schaal te ontwikkelen voor het meten van het geloof in eigen kunnen met betrekking tot rolstoelmobiliteit (SEWM). Deze schaal werd ontwikkeld met het oog op twee doelstellingen: (a) het rekruteren van de meest bekwame personen met een dwarslaesie (met betrekking tot rolstoelmobiliteit), dit om een panel van deskundigen te genereren die met hun expertise en ervaring de onderzoekers adviseren tijdens het ontwikkelen van de standaard test van rolstoelmobiliteit; en (b) om bewijs te verzamelen voor de validiteit van de test die ontwikkeld zal worden in deze studie, dit door het correleren van beide testresultaten. Daarnaast zijn er vele toepassingsmogelijkheden voor deze test te vinden in zowel klinische als maatschappelijke kringen die gericht zijn op rolstoelmobiliteit bij personen met een dwarslaesie. Een meetschaal die het geloof in eigen kunnen bij rolstoelmobiliteit test, hebben we niet gevonden in de internationale literatuur. De belangrijkste resultaten van deze studie (n=47, enkel paraplegie) toonde een hoge interne consistentie van de SEWM, slechts twee items vertoonden lage correlaties met de totale score. De conclusie van deze studie was dat de SEWM een betrouwbaar en valide meetinstrument is bij manuele rolstoelgebruikers met een dwarslaesie, maar voor items 8 en 9 werd het advies gegeven om ze aan te passen en een grotere steekproef (met inbegrip van personen met tetraplegie) is nodig om de statistische eigenschappen van de schaal verder te ondersteunen.

Tijdens de Paralympische spelen 2008 in Peking werd de gelegenheid te baat genomen om de psychometrische bevindingen van de SEWM schaal uit hoofdstuk 4 te testen, na herformulering van de items 8 en 9 (hoofdstuk 5). De atleten met een dwarslaesie die dynamische rolstoelsporten beoefenden en de atleten die meer statische en niet-rolstoelsporten beoefenden, werden vergeleken op de perceptie van het geloof in eigen kunnen. De resultaten bevestigden de hoge interne consistentie en constructvaliditeit van de SEWM. Verder onderzoek van de subgroepen toonde ook aan dat atleten met tetraplegie een significant lagere score haalden dan de atleten met paraplegie. Daarnaast bleek ook dat atleten die deelnamen aan dynamische rolstoelsporten het hoogste geloof in eigen kunnen hadden en de atleten die deelnamen aan statische rolstoelsporten het laagste.

Een enquête onder eliteatleten met een dwarslaesie werd eveneens uitgevoerd tijdens de Paralympische Spelen in Peking met als doel om de meest essentiële vaardigheden voor rolstoelmobiliteit voor het dagelijkse leven uit te zoeken, dit om deze vaardigheden te integreren in de test van rolstoelmobiliteit (hoofdstuk 6).

Naast de lijst van vaardigheden, toonden de resultaten van deze enquête ook aan dat bijna de helft van de deelnemers de meeste van de essentiële rolstoelvaardigheden pas had geleerd in de periode na de klinische revalidatie.

Na de kritische literatuurstudie (hoofdstuk 2), het ontwikkelen van de SEWM meetschaal (hoofdstuk 4 & 5) en het oplijsten met de meest essentiële rolstoelvaardigheden voor het dagelijkse leven (hoofdstuk 6), werd er een “team van experts” samengesteld met daarin manuele rolstoelgebruikers die alle laesiehoogten vertegenwoordigen, alsook kinesitherapeuten en academici. Het doel van dit “team van experts” was om de test van rolstoelmobiliteit (TOWM) te ontwikkelen. Bovendien was de idee gegroeid om een kortere Wheelie test te ontwikkelen, dit op basis van de veronderstelling dat het beheersen van een wheelie gepaard gaat met een betere rolstoelvaardigheid.

Het verloop van de ontwikkeling van de test was iteratief, met herhaalde herzieningen, try-outs en vele aanmerkingen van het team van experts. De TOWM en de korte Wheelie test werden beiden getest op haalbaarheid, validiteit (hoofdstuk 7) en betrouwbaarheid (hoofdstuk 8). Beide testen bleken valide en betrouwbaar te zijn voor het beoordelen van rolstoelmobiliteit bij manuele rolstoelgebruikers met een dwarslaesie[1].

In het laatste deel van dit proefschrift (hoofdstuk 9) worden er een aantal methodologische overwegingen, praktische gevolgen en aanbevelingen voor verder onderzoek besproken. De belangrijkste suggestie die werd gedaan is om, na herformulering van enkele kwaliteitscriteria en het weglaten van de taak "voortstuwing op vlak terrein", de TOWM toe te passen in een grotere steekproef, met daarbij ook personen met een dwarslaesie in een revalidatiefase. Daarnaast zou de effectiviteit van interventies getest moeten worden door gebruik te maken van de TOWM.

Als laatste punt werd aangeraden om te onderzoeken of het trainen en aanleren om een wheelie te beheersen (dit gebaseerd op het protocol van de Wheelie test) ook de prestatie op de TOWM vaardigheden zal verbeteren. Een positief resultaat zou kunnen betekenen dat de kortere en meer economische Wheelie test kan dienen als alternatief voor de TOWM.

De onderzoekster drukt tot slot haar hoop uit dat de uiteindelijke versie van de TOWM en de Wheelie test wereldwijd gebruikt zullen worden door de revalidatiegemeenschap, en dat er door veelvuldig gebruik, normwaarden kunnen worden ontwikkeld voor rolstoelmobiliteit volgens laesiehoogte en aard van het letsel.

[1]De testprotocols van de TOWM, de Wheelie test en de SEWM-schaal zijn in meerdere talen samen met de gesorteerde lijst van de meest essentiële rolstoelvaardigheden vrij te verkrijgen op: www.scionn.nl/inhoudp28.htm.

תקציר וסיכום בעברית

הנעת כיסא הגלגלים הינה חיונית ביותר לתפקוד היומיומי של נפגעי חוט שדרה ועשויה לתרום רבות לשילובם ומידת השתתפותם בפעילויות חברתיות ובלקיחת תפקידים חברתיים. לכן, אחת המטרות המרכזיות בתהליך השיקום של נפגעי חוט שדרה היא לימוד מיומנויות הנעת כיסא הגלגלים ושיפור השליטה בכיסא הגלגלים תוך שימת דגש על המיומנויות להן יזדקקו ביומיום. שליטה בהנעת כיסא הגלגלים תעשה את ההבדל בין תלותיות לעצמאות בקרב נפגעי חוט שדרה.

על פי הקלסיפיקציה של ארגון הבריאות הבינלאומי לתפקוד, מגבלה ובריאות (ICF WHO 2001). תנועה בכיסא גלגלים מוגדרת כתת קטגוריה של "תנועה בעזרת מכשיר עזר": העברת הגוף כולו ממקום למקום, על כל משטח שהוא, על ידי שימוש באמצעי עזר אשר עוצב במיוחד כדי לסייע להנעת הגוף במרחב ולאפשר דרכים חלופיות לתנועה, לדוגמה: גלגיליות, מגלשי סקי, מכשירי צלילה, או תנועה במורד הרחוב בעזרת כיסא גלגלים או הליכון. לאנשים עם פגיעה בחוט השדרה, הגדרה זו מתייחסת ליכולתם לנוע בעזרת כיסא גלגלים בסביבה משתנה ולעיתים קרובות אף מאתגרת.

יכולת התפקוד של נפגעי חוט שדרה משתנה מאדם לאדם ותלויה בגורמים רבים: גובה הפגיעה (הסיגמנט העצבי), מידת הקרע (מוחלט או חלקי), ההתאוששות הנוירולוגית, סיבוכי משנה (ספסטיות, קונטרקטורות), משך השיקום ומידת היעילות של תהליך השיקום בעת האשפוז הראשוני, גיל הפציעה, משקל גוף, מוטיבציה, תמיכה משפחתית, מצב סוציו-אקונומי ועוד. על פי הספרות, מבין הגורמים המשפיעים ביותר על לימוד מיומנויות בכיסא הגלגלים והגעה לעצמאות מכסימלית, הינם אלו הקשורים לתפיסות ועמדות (מרכיבים פסיכולוגים) ולאו דווקא לגורמים גופניים ולמידת הנכות הפיזית (Nosek et al., 1995).
לכן, כשמלמדים ובוחנים מיומנויות בכיסא גלגלים, האספקטים הפסיכולוגיים (כגון, תחושת מסוגלות עצמית, חרדה, מוטיבציה), צריכים להילקח בחשבון ולבוא לידי ביטוי.

ההנחה הבסיסית של עבודת הדוקטורט הזו היא שרמת הניידות בכיסא גלגלים כפי שנרכשת כיום במהלך השיקום אינה אופטימאלית. מכאן שנפגעי חוט שדרה המשתחררים ממחלקות השיקום אינם מוכנים (מבחינת הידע ורמת הניידות בכיסא גלגלים) לאתגרים הסביבתיים המצפים להם מחוץ למחלקה הנגישה והמוגנת.

מיומנויות הנעת כיסא הגלגלים הנלמדות בתקופת השיקום בבית החולים צריכות להיות מותאמות לצרכים ולפעילויות של כל מטופל. הן צריכות למקסם את יכולתו של האדם להיות עצמאי ולהפחית את התלותיות שלו באחרים. על המטפלים במחלקות השיקום לרכוש ידע ולחפש דרכים לשיפור מיומנות התנועה בכיסא הגלגלים בקרב מטופליהם, ובכך, לקדם את מידת השתתפותם בפעילויות בקהילה ולקיחת תפקידים חברתיים.
בנוסף, למטפלים נדרש כלי אבחון תקף, אמין, מהימן ורגיש על מנת שיוכלו להעריך בדרך אובייקטיבית וסיסטמתית, את רמת מיומנויות התנועה בכיסא הגלגלים בקרב מטופליהם במהלך ובסיום תהליך השיקום.

מבדק מיומנות תנועה בכיסא גלגלים מכיל משימות שונות אשר מבוצעות על ידי הנבחן בתנאים מתוקננים (תנאים שווים וקבועים לכל נבחן). מבדק תקף ומהימן דרוש כדי לשמש ככלי מנחה בתהליך השיקום של נפגעי חוט שדרה, ולמטופלים נוספים עם פגיעות בגפיים התחתונות. מבדק כזה יכול לסייע באבחון, בקביעת המטרות ובהערכת ההתקדמות של המטופל וכן לתת משוב לגבי אפקטיביות הטיפול.

קיימים מבדקים רבים להערכת מיומנויות תנועה בכיסא גלגלים. עובדה זו מקשה על היכולת להשוות תוצאת ממחקרים שונים. בנוסף, שימוש במבדק אחיד ומקובל על כולם יאפשר קביעת נורמות וסטנדרטים לרמת מיומנות משוערת שאליה יש לשאוף על פי גובה הפגיעה בחוט השדרה. מבדק אחיד כזה קיים עד כה (Kilkens et al., 2003).

מטרת מחקר זה הייתה לפתח מבחן סטנדרטי לבדיקת מיומנויות תנועה בכיסא גלגלים (תום – **ת**נועה **ומ**יומנות / TOWM –Test of wheeled mobility), המיועד לנפגעי חוט שדרה המשתמשים באופן קבוע בכיסא גלגלים ידני.

שאלת המחקר העיקרית הייתה אילו מיומנויות, סולמות מדידה וציוד צריכים להיכלל במבחן אוניברסאלי הבודק מיומנויות תנועה כיסא גלגלים בקרב נפגעי חוט שדרה, על מנת שהמבחן יהיה תקף, מהימן, רגיש, מבדיל בין רמות תפקוד שונות ורמות פגיעה שונות, נוח, זול ומהיר לשימוש.

במחקר הראשון (פרק 2), נערכה סקירה ספרותית. המטרה העיקרית של המחקר הייתה לסקור באופן שיטתי, לנתח באופן ביקורתי ולהעריך את מבדקי המיומנויות בכיסא גלגלים שפותחו עבור משתמשים בכיסא גלגלים ידני, (במיוחד אלו עם פגיעה בחוט השדרה), הזמינים כיום בספרות הבינלאומית. הערך המוסף של הסקירה היה שבסופה ניתן היה לזהות את המרכיבים החשובים והקריטיים ביותר מתוך מבחני המיומנויות הקיימים, עליהם ניתן יהיה לבסס את פיתוחו של המבדק האוניברסאלי.

כדי לבדוק את ההנחה הראשונית לגבי רמת המיומנות בהנעת כיסא גלגלים שנרכשה בשלב השיקום, בוצע מחקר בקרב נפגעי חוט שדרה הבודק את ההבדלים ברמת ביצוע מיומנויות תנועה בכיסא גלגלים בין יום השחרור ושנה לאחר מכן (פרק 3). הנתונים למחקר נלקחו ממחקר אורך הנעשה בהולנד ונקרא "פרויקט המטרייה". רמת הניידות בכיסא גלגלים נבדקה על ידי ה "Wheelchair Circuit" (Kilkens et al., 2004). בנוסף, נעשה ניסיון גם לברר אילו גורמים אישיים וסביבתיים תורמים באופן המשמעותי ביותר לשינוי רמת הניידות. תוצאות המחקר הראו כי בהתבסס על ה "Wheelchair Circuit", רמת מיומנויות התנועה בכיסא גלגלים אינה משתנה (מתייצבת) במהלך השנה הראשונה שלאחר השחרור מבית החולים. היבטים אישיים כגון גובה הפגיעה, גיל, מגדר ועוד לא נמצאו משפיעים על שינויים בתפקודי הניידות. תחושת מסוגלות עצמית נמצאת כגורם המשפיע על שיפור מיומנויות תנועה בכיסא גלגלים. מסקנת המחקר העיקרית הייתה שה- "Wheelchair Circuit" אינו מתאים לבחון רמת מיומנויות הנעת כיסא גלגלים לאחר השחרור מבית החולים בשל "אפקט התקרה" (מרבית הנבדקים השיגו את התוצאה הגבוהה ביותר בתום השיקום ולכן, שיפור לא יכול היה להיות מודגם).

מטרת המחקר הבא (פרק 4) הייתה לפתח ולבדוק את התקפות והמהימנות של "שאלון תחושת מסוגלות עצמית בהנעת כיסא גלגלים" (SWEM). כלי מדידה זה פותח לצורך שתי מטרות: א) על מנת לגייס נפגעי חוט שדרה בעלי תפיסת מסוגלות גבוהה ברמת הניידות שלהם בכיסא גלגלים, כדי להקים פאנל מומחים איתם צוות המחקר ייוועץ בעת פיתוח המבדק האוניברסאלי, ו- ב) כדי להשתמש בכלי הזה לצורך בדיקת התקפות של המבדק האוניברסאלי על ידי בדיקת מתאם בין שני המבחנים. בנוסף, כלי מדידה תקף ומהימן המעריך את מידת תחושת המסוגלות העצמית בהנעת כיסא גלגלים יכול למצוא יישומים רבים כשמודדים את מידת מסוגלות הניידות העצמאית של מרותקים לכיסאות גלגלים בכלל, ושל נפגעי חוט שדרה בפרט. ניתן להשתמש בשאלון כזה לבדיקת התקדמות בעת השהות במרכז השיקום, או בסדנאות לשיפור תנועה בכיסא גלגלים לאחר השחרור מבית החולים. תחושת המסוגלות העצמית בהנעת כיסא הגלגלים עשויה לנבא את היכולת האמיתית של אותו נבדק לנוע באופן עצמאי בעזרת כיסא הגלגלים. שאלון ספציפי לבדיקת תחושת המסוגלות העצמית בהנעת כיסא גלגלים לא נמצא בספרות הבינלאומית. התוצאות העיקרי, של המחקר (בהתבסס על 47 משתתפים, כולם פרפלגים), הייתה שהשאלון תקף ומהימן אך פריטים 8 ו- 9 הפחיתו במידת מה את העקביות של המבדק. בנוסף, הומלץ לבחון את השאלון גם עם נפגעי חוט שדרה בעלי פגיעה צווארית (קוואדריפלגיה).

במהלך המשחקים הפראלימפיים בבייג'ין 2008 ניתנה ההזדמנות לתמוך בממצאים הראשוניים של "שאלון תחושת מסוגלות עצמית בהנעת כיסא גלגלים" (SWEM), לאחר הניסוח החדש של סעיפים 8 ו - 9 (פרק 5). במחקר זה, בנוסף לבדיקה מחודשת של התקיפות והמהימנות של השאלון, נערכה השוואה בין תפיסת

המסוגלות העצמית בהנעת כיסא גלגלים בין ספורטאים בעלי גובה פגיעה שונה ובין ספורטאים המתחרים בענפי ספורט שונים. ממצאי המחקר הראו כי "שאלון תחושת המסוגלות העצמית בהנעת כיסא הגלגלים" הינו תקף ומהימן (במספר שפות, כולל בעברית). על פי תוצאות השאלון נמצא כי יש הבדל מובהק בין ספורטאים המשתתפים בענפי ספורט דינאמיים בכיסאות גלגלים (תפיסת מסוגלות עצמית גבוהה יותר) לבין אלה המשתתפים בענפי ספורט ללא כיסאות גלגלים (לדוג' שחייה, חתירה, הרמת משקולות ועוד).

במקביל למחקר הזה, במהלך המשחקים הפארלימפיים בבייג'ין נערך גם סקר בקרב ספורטאים בעלי פגיעה בחוט השדרה, במטרה לברר אילו מיומנויות תנועה בכיסאות גלגלים הן הכי חיוניות בחיי היומיום, על מנת לשלב את המיומנויות שדורגו כ"הכי חיוניות" במבדק האוניברסאלי (פרק 6). מלבד הרשימה ההיררכית על פי חשיבות המיומנויות, עוד התברר כי כמחצית ממשתתפי הסקר רכשו את מיומנויות התנועה בכיסא גלגלים שדורגו כהכי חיוניות לאחר השחרור מהשיקום בבית החולים.

בשלב הזה, כשלרשות צוות המחקר הייתה סקירה ספרותית ביקורתית, שאלון "תחושת מסוגלות עצמית בהנעת כיסא גלגלים" וכן רשימה ממוינת של המיומנויות החיוניות ביותר בחיי היומיום, הורכב צוות מומחים על מנת לפתח את המבחן לבדיקת מיומנויות תנועה בכיסא גלגלים (TOWM). פאנל המומחים כלל נפגעי חוט שדרה המייצגים רמות פגיעה שונות, פיזיותרפיסטים ואנשי מקצוע אקדמאים. במקביל לפיתוח ה- TOWM, הועלה רעיון לפתח גם מבדק ווילי קצר (ווילי = איזון על הגלגלים האחוריים short Wheelie test). ההנחה שביסודה עמד רעיון זה היא ששליטה מלאה במיומנויות ווילי, תביא לתפקוד טוב יותר בעת ביצוע מיומנויות תנועה בכיסא הגלגלים. לאחר סיעור מוחות, ביקורות והערות חוזרות ונשנות של פאנל המומחים ומבדקים ניסיוניים, הושלם הפרוטוקול של שני המבחנים.

במחקר הבא נבדקו התקיפות, המהימנות, הכדאיות והישימות (בהיבט זמן, בטיחות, עלות הציוד, יעילות וכו') הן של ה TOWM והן של מבדק הווילי הקצר (פרקים 7 ו- 8). שני המבדקים נמצאו תקפים, מהימנים, בטוחים לשימוש, נוחים וזולים ומתאימים להבדיל בין רמות תפקוד שונות בעת ביצוע מיומנויות תנועה בכיסא גלגלים בקרב נפגעי חוט שדרה[1].

בחלק האחרון של עבודה זו (פרק 9), מספר היבטים מתודולוגיים, השלכות מעשיות והמלצות למחקר עתידי נדונו. ההצעה העיקרית הייתה כי לאחר מספר קטן של שיפורים, יש לבחון בעזרת ה TOWM מדגם גדול יותר הכולל מטופלים אשר נמצאים עדיין במחלקות השיקום וכן יש להעריך בעזרת ה TOWM את האפקטיביות של תוכנית התערבות ללימוד ושיפור מיומנויות תנועה בכיסא גלגלים.

הצעה נוספת שהועלתה היא לבחון האם ניתן להחליף את מבדק ה TOWM (הכולל 30 מיומנויות), במבדק הווילי הקצר (הכולל 8 מיומנויות בלבד). הרעיון הוא לחקור האם כתוצאה מהכלת תוכנית מתערבת ללימוד ותרגול מיומנויות הווילי (בהתבסס על הפרוטוקול של ה Wheelie test, ישתפר בהכרח גם ביצוע המיומנויות הנכללות ב TOWM.

לסיכום, החוקרת הביעה את תקוותה כי הפרוטוקול הסופי של ה TOWM ושל ה Wheelie test יתקבל ויאומץ על ידי קהילת השיקום הבינלאומית, ויחל שימוש קבוע במבדקים אלו, על מנת לקבוע נורמות וסטנדרטים למיומנויות תנועה בכיסא גלגלים בהתאם לגובה הפגיעה בחוט השדרה.

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[1] הפרוטוקול של ה TOWM וה Wheelie test, שאלון "תחושת מסוגלות עצמית בהנעת כיסא גלגלים" בשפות שונות (SWEM) וכן הרשימה הממוינת של מיומנויות תנועה בכיסא גלגלים על פי החיוניות ביומיום, זמינים באתר: www.scionn.nl/inhoudp28.htm

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This thesis was also made possible by being lucky enough to be introduced to my promoter, Prof. Dr. Lucas van der Woude, whose encouragement, guidance and support, from the first to the final stages, enabled me to develop a comprehensive understanding of the complex dimensions of the field of rehabilitation sciences. Prof. van der Woude is a personal role model for me in many ways, including his modesty, as well as his love and respect for people from all walks of life. With him too, I look forward to our continuing work together.

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My parents Uri and Aviva Fliess followed the process of the research over the years. Sadly my father passed away two years before its completion. As a token of my appreciation to my parents' love and support throughout my life, I dedicate this thesis to them.

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And the last special thank belongs to my dear husband Nir, for his love, patience and encouragement, for believing in me and my abilities, for helping me in any needed task. Without you, and your endless support, I would never have accomplished this challenge. I feel you deserve receiving a PhD today too. Thank you so much.

Toda Raba! Bedankt!

About the author

Osnat Fliess-Douer was born on April 10th 1971 and grew up in Binyamina Israel. Between 1990-1992 she served in the Israeli Defense Forces as an instructor in a military engineers unit specializing in the removal of explosives. From 1993 to 1996 she studied for her B.Ed. in Physical Education and Sports at Wingate College Israel, with a major in Sports Rehabilitation. During her studies, Osnat followed aquatic technique courses and specialized in hydrotherapy and adapted swimming. On the last year of her B.Ed. studies, Osnat was invited by Dr. Shayke Hutzler, the head of the Department of Sport Rehabilitation for the disabled, to work part time as a research assistant. As an ex-basketball player who also holds basketball coach certification, Osnat served as assistant coach at Ilan Haifa wheelchair basketball team in 1996. Between 1997 and 1998 Osnat followed the EMDAPA program (European Master's degree in Adapted Physical Activity) at the Catholic University of Leuven, Belgium. In 1999 Osnat was qualified for silver classifier in wheelchair basketball in Roermond, The Netherlands. After returning to Israel, Osnat worked at Ilan – Sport Center for the Disabled in Ramat-Gan as the head of the "Children and youth rehabilitation activity program". Between 1999 and 2008 she was appointed lecturer at the Department of Sport Rehabilitation for the disabled at Wingate College, and between 2003 and 2006 she was appointed lecturer at Bar–Ilan University, School of education, at the Department of education for children with special needs. From 2004 until present time Osnat is the director of the hydrotherapy courses at Wingate College. In 2005, Osnat opened a private health clinic: "Multipool - Binyamina's Jahara® Center", offering both, land and water-based therapies, and in 2006 she was qualified as a Jahara® aquatic therapy international teacher.

For the last 10 years Osnat was coaching wheelchair basketball at the highest league in Israel and between 2008 and 2010 she was the coach of Israel women's national wheelchair basketball team. In January 2007 she applied for a PhD at the Department of Rehabilitation Sciences, at the Catholic University of Leuven, Belgium, supervised by Prof. Dr. Yves Vanlandewijck and by Prof. Dr. Lucas HV van der Woude from the Center for Human Movement Sciences, Center for Rehabilitation, University Medical Center Groningen, The Netherlands. In 2010 Osnat was nominated as a member in the Sport Science Committee of the International Paralympic Committee (IPC, SSC).

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