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Relationship between manual wheelchair skill performance and participation of persons with spinal cord injuries 1 year after discharge from inpatient rehabilitation

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Abstract—This cross-sectional study describes the level of manual wheelchair skill performance and participation of persons with spinal cord injuries (SCIs) 1 year after discharge from inpatient rehabilitation and tests the hypothesis that wheelchair skill performance is positively related to participation. Participants included 81 persons with SCI from eight rehabilitation centers in the Netherlands. The Wheelchair Circuit consists of eight wheelchair skills and results in three test scores: ability, performance time, and physical strain. Participation was assessed with the sum of the subscales Mobility Range and Social Behavior of the 68-Item Sickness Impact Profile (SIPSOC). SIPSOC was moderately related to the ability score (the Spearman rank correlation [r_S] = –0.49), the performance time score (r_S = 0.54), and the physical strain score (r_S = 0.38). The regression analyses showed that, after controlling for lesion and personal characteristics, manual wheelchair skill performance is positively related to participation, with the strongest association for the performance time score. In persons with SCI who are manual wheelchair users, wheelchair skill performance is moderately associated to participation. Training of wheelchair skills has to be an important goal of rehabilitation, and persons should be stimulated to maintain their wheelchair skills after discharge from rehabilitation.

Key words: hand-rim wheelchair, lesion characteristics, participation, physical strain, rehabilitation, Sickness Impact Profile, sociodemographic variables, spinal cord injury, training, wheelchair skill.

INTRODUCTION

Many persons with a spinal cord injury (SCI) use a wheelchair for mobility in daily life. In the Netherlands, approximately 82 percent of individuals with SCI who are admitted for inpatient rehabilitation are wheelchair users and 60 percent completely depend on a wheelchair for their mobility [1]. To function independently, manual

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Abbreviations: ADL = activity of daily living; ASIA = American Spinal Injury Association; CHART = Craig Handicap Assessment and Reporting Technique; ICF = International Classification of Functioning, Disability and Health; %HRR = percentage heart rate reserve; SCI = spinal cord injury; SIP68 = 68-Item Sickness Impact Profile; SIPSOC = sum of the subscales Mobility Range and Social Behavior of the SIP68.

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wheelchair users must posses certain wheelchair skills, i.e., the ability to use a wheelchair in different ways and circumstances, such as moving forward and backward, turning around, and negotiating a curb to deal with the physical barriers they will inevitably encounter in various environments [2]. Mastering wheelchair skills can make a difference between dependence and independence in daily life [3–4], and therefore, wheelchair skill training is a vital part of the rehabilitation process. Kilkens et al. and MacPhee et al. showed that during the primary inpatient rehabilitation of persons with SCI, wheelchair skill performance improved significantly [5–6]. When persons with acute SCI are discharged from inpatient rehabilitation, most of them can indeed propel their wheelchair and perform various wheelchair skills, such as negotiating curbs and transferring [5].

Participation is also an important rehabilitation outcome for persons with SCI. In the International Classification of Functioning, Disability and Health (ICF), participation is defined as "involvement in life situations," including, for example, work and school, house-keeping, social relationships, and community organizations. Participation restrictions are the problems an individual may have involving life situations [7]. Activity limitations are defined in the ICF as the difficulties an individual may have executing a task, such as washing the upper body, walking, or using a wheelchair [7]. From the literature, we know that persons with activity limitations experience participation restrictions in daily life [8–12]. The relationships between the severity of the SCI, activity limitations, and participation are however unclear. In some studies, an inverse relation between the severity of the injury and participation was found [13–14], while other studies could not demonstrate an association between these variables [9,15–16].

As stated earlier, wheelchair skill performance plays an important role in the independent performance of activities of daily life (ADLs). One can expect that a positive relationship exists between manual wheelchair skill performance and participation in persons with SCI; however, this has never been studied.

In the present study, we describe the level of manual wheelchair skill performance and participation in persons with SCI 1 year after discharge from inpatient rehabilitation and test the hypothesis of a positive relationship between manual wheelchair skill performance and participation.

METHODS

Participants and Procedure

The present cross-sectional 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."* For this present study, persons with SCI were measured 1 year after discharge from inpatient rehabilitation. 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 65; 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 problem; 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 medical doctor. Potential subjects 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. 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. An accredited medical ethics committee approved all tests and protocols.

Demographic Characteristics

Literature has shown that participation of persons with SCI is related to age [13–14,17], gender [17–18], and educational level [13–14,17,19]. Therefore, age at the time of the measurement, gender, and educational level were assessed and included as covariates in the statistical analyses. Educational level was coded into three categories:

1. Low (i.e., primary school, lower vocational education or lower secondary education).

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2. Medium (upper secondary education or intermediate vocational education).
3. High (upper vocational education or university).

Lesion Characteristics

A physician assessed the lesion characteristics according to the International Standards for Neurological Classification of Spinal Cord Injury [20]. The ASIA classifications A and B were defined as motor complete and classes C and D as motor incomplete. Neurological lesion levels below T1 were defined as paraplegia, while lesion levels at or above T1 were defined as tetraplegia.

Participation

Participation was measured with the 68-Item Sickness Impact Profile (SIP68). The SIP68 is a questionnaire that measures health-related functional status by assessing the impact of disease or disability on behavioral limitations [21]. We chose the SIP68 because it is a reliable and valid measure for use in SCI [21–22] and its measurement concept compares closely with the ICF [7]. The questionnaire consists of six subscales. According to the ICF model, four subscales measure activity limitations (i.e., Somatic Autonomy, Mobility Control, Emotional Stability, and Psychological Autonomy and Communication) and two subscales measure participation (Mobility Range and Social Behavior). Following Post et al. [14,21], we will use the sum of the subscales Mobility Range and Social Behavior of the SIP68 (SIPSOC), to measure participation. The items of SIPSOC are displayed in **Table 1**. Most items concern domestic life and interpersonal interactions and relationships domains; parts of the major life areas domain; and the community, social, and civic life domain.

The Wheelchair Circuit

The Wheelchair Circuit [23–24] is a test to assess wheelchair skill performance. It was developed and validated for this study because at the start of the study (1999), no well-described and validated wheelchair skills tests were available [24]. 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 subjects 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).

Table 1.
Item scores of sum of subscales Mobility Range and Social Behavior of 68-Item Sickness Impact Profile (SIPSOC) (in order of ascending values): proportion of persons with a spinal cord injury suffering from certain participation problems (*n* = 80).

SIPSOC Item	% "Applies to Me"
I am not going out to visit people at all.	2.5
I am getting around only within one building.	6.3
I have given up taking care of personal or household business affairs, for example, paying bills, banking, working on budget.	7.5
I am not going into town.	11.3
I stay away from home only for brief periods of time.	11.3
I am cutting down on some of my usual inactive recreation and pastime, for example, watching TV, playing cards, reading.	11.3
I do not get around in the dark or in unlit places without someone's help.	13.8
I am cutting down the length of visits with friends.	18.8
I am doing fewer social activities with groups of people.	18.8
I do my hobbies and recreation for shorter periods of time.	22.5
I am drinking less fluids.	22.5
I stay at home most of the time.	23.8
I am doing fewer community activities.	26.3
I am not doing any of the regular work around the house that I would usually do.	28.8
I am not doing any of the shopping that I would usually do.	30.0
I am not doing any of the clothes washing that I would usually do.	32.5
I am not doing any of the housecleaning that I would usually do.	33.8
I am going out for entertainments less often.	33.8
I am eating much less than usual.	33.8
I am doing less of the regular daily work around the house than I would usually do.	60.0
My sexual activity is decreased.	61.3
I am not doing heavy work around the house.	71.3

The eight tasks are performing a figure eight; crossing a doorstep (height, 0.04 m); mounting a platform (height, 0.10 m); and performing a 15 m sprint, 3 percent slope, 6 percent slope, 3 min wheelchair propulsion, and transfer. For the slope tests, participants are asked to drive at the given slope for 10 s. The total time needed for the 3 and 6 percent slopes is about 45 s and 65 s, respectively. During the performance of the circuit, the ability to perform the test items, the performance time of the figure eight and the 15 m sprint, and the peak heart rates during the 3 and 6 percent slope tests on the treadmill were recorded. The heart rate (b/min) was registered with a Polar sport tester Vantage NV at a 5 s storage interval (Polar Electro Inc., Finland). The performance of the Wheelchair Circuit leads to three different test scores: ability, performance time, and physical strain.

Ability Score

All test items that are performed adequately and independently are assigned 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 15 m sprint could not be assigned a performance time score.

Physical Strain Score

The mean of the peak heart rates reached during each of the two slope tests is expressed as percentage heart rate reserve (%HRR), with the HRR being the difference between the maximum heart rate and the heart rate at rest [25]. The maximum heart rate was assessed during a maximum wheelchair exercise test, while the resting heart rate was measured after a 5 min rest. The protocol of the maximum wheelchair exercise test has been previously described in detail [24]. The physical strain score indicates how easily a certain ADL is accomplished and is thereby a measure of skill [26]. Subjects who were not able to perform both the 3 and 6 percent slope tests and/or the maximum wheelchair exercise test could not be assigned a physical strain score.

The content and the development of the Wheelchair Circuit have been described in detail in previous studies [23–24]. Mean intrarater and interrater reliability intraclass correlations ranged from 0.81 to 0.92 [23]. Construct validity was demonstrated by strong relationships with measures of functional status, physical capacity, and lesion characteristics [24].

Statistical Analysis

We performed analyses using SPSS (Statistical Package for the Social Sciences) (version 11.0). We used descriptive statistics to describe wheelchair skill performance and participation 1 year after discharge from inpatient rehabilitation.

Since most measures were of an ordinal level or showed a nonnormal distribution, we used nonparametric techniques to examine bivariate relationships between the variables used in this study: Kendall's tau for associations between dichotomous variables and between dichotomous and ordinal variables, and Spearman correlations for the associations between ordinal variables.

To examine the proposed positive association between wheelchair skills and participation, we applied hierarchical regression analyses. For each score of the Wheelchair Circuit, a three-step analysis was performed with the variables age, gender, and educational level (step 1); lesion level and motor completeness (step 2); and the Wheelchair Circuit score (step 3). A fourth and final regression model used all three scores of the Wheelchair Circuit together in step 3. For each predictor, these regression analyses reveal a standardized regression coefficient β, indicating the strength of the relationship of the predictor variable with the dependent variable corrected for the influence of other predictor variables, and for each step, the amount of variance that is explained by all variables together (Adjusted R^2). The expected increase of total explained variance at each following step was tested for statistical significance.

RESULTS

Eighty-one participants completed the SIP68 questionnaire and performed the Wheelchair Circuit 1 year after discharge from inpatient rehabilitation. Their mean age ± standard deviation was 39.3 ± 13.9 years (range 20–67 years) and 56 (69%) were men. There were 56 (69%) persons with paraplegia, including 17 persons with a motor incomplete lesion, and 25 (31%) persons with tetraplegia, including 13 persons with a motor incomplete lesion. Educational level was low for 26 persons (32%), medium for 36 persons (44%), high for 16 persons (20%), and unknown for 3 persons (4%).

Not all participants were able to obtain all three scores of the Wheelchair Circuit. All 81 subjects had an ability score, 76 had a performance time score, but only 49 had a physical strain score. Participants who were able to obtain the physical strain score were younger (36.6 vs. 43.3 yr; $p = 0.034$); were more often paraplegic (85.7% vs. 43.8%; $p < 0.001$), and had better median ability scores (8 vs. 5; $p < 0.001$), performance time scores (16 vs. 29; $p < 0.001$), and SIPSOC scores (5 vs. 7; $p = 0.005$) than subjects without a strain score.

Table 2 shows the scores on SIPSOC and the Wheelchair Circuit. The distribution of the ability score was strongly skewed, with a median score of 7.5 on a scale range of 0 to 8. This finding means that most people had a high level of wheelchair skills. SIPSOC showed that most participants suffered from participation restrictions. Only 10 participants (12.3%) reported no restrictions at all (SIPSOC = 0). In **Table 1,** the proportion of participants reporting certain participation restrictions taken from SIPSOC is displayed. More than two-thirds of the participants were doing less work in and around their house and were less sexually active because of the SCI. Visiting other people, going out of the house, and taking care of personal and financial business were least often affected by the SCI. In **Table 3**, the bivariate correlations between demographic characteristics, lesion characteristics, Wheelchair Circuit scores, and participation are displayed.

Table 2.
Distribution of scores on the wheelchair skills test (Wheelchair Circuit) and participation (SIPSOC).

Score	*N*	Range	Mean ± SD	Median	IQR
SIPSOC	81	0–18	6.0 ± 4.2	5.0	3.0–9.0
Ability	81	0–8	6.3 ± 2.4	7.5	5.0–8.0
Performance Time (s)	76	11–57	21.4 ± 10.4	17.0	14.0–25.0
Physical Strain (%HRR)	49	5.5–72.0	33.5 ± 16.2	28.9	21.5–44.0

SD = standard deviation
IQR = interquartile range
SIPSOC = sum of subscales Mobility Range and Social Behavior of 68-Item Sickness Impact Profile
%HRR = percentage of heart rate reserve

Table 3.
Bivariate relations between demographic variables, lesion characteristics, Wheelchair Circuit scores, and sum of subscales Mobility Range and Social Behavior of 68-Item Sickness Impact Profile (SIPSOC) score (*n* = 45–75).

	Age	Gender	Educational Level	Lesion Level	Motor Completeness	Ability Score	Performance Time Score	Physical Strain Score
Age*	—	—	—	—	—	—	—	—
Gender†	–0.12	—	—	—	—	—	—	—
Educational Level†	–0.18	0.22‡	—	—	—	—	—	—
Lesion Level†	–0.03	–0.04	0.07	—	—	—	—	—
Motor Completeness†	–0.39§	0.09	0.07	0.19	—	—	—	—
Ability Score*	–0.38§	0.15	0.08	0.57§	0.18	—	—	—
Performance Time Score*	0.53§	–0.21	–0.34§	–0.48§	–0.18	–0.79§	—	—
Physical Strain Score*	–0.03	0.07	–0.05	–0.28§	0.10	–0.36§	0.41§	—
SIPSOC Score*	0.34§	–0.13	–0.06	–0.26‡	–0.05	–0.49§	0.54§	0.38§

Note: Gender was coded as 0 = female, 1 = male; educational level as 0 = low, 1 = medium, and 2 = high; lesion level as 0 = tetraplegia, 1 = paraplegia; and motor completeness as 0 = incomplete, 1 = complete.
*Continuous variables: Spearman correlations (r_S)
†Dichotomous variables: Kendall's tau
‡$p \leq 0.05$
§$p \leq 0.01$

The SIPSOC score was moderately related to all three Wheelchair Circuit scores. Persons who had fewer participation restrictions showed higher ability scores (r_S = –0.49), lower performance time scores (r_S = 0.54), and lower physical strain scores (r_S = 0.38) on the Wheelchair Circuit. Participation was also moderately correlated to age (r_S = 0.34) and weakly related to lesion level (r_S = –0.26).

Table 4 shows the results of the multiple regression analyses. In the first model, the addition of the ability score at step 3 increased the amount of explained variance by 5 percent ($p < 0.05$). In the final model, only age and the ability score significantly predicted participation. In the second model, with the use of the performance time score, the results were comparable, the time score adding 6 percent explained variance ($p < 0.05$). In the third model using the physical strain score ($n = 47$), hardly any variance was explained by demographic and injury characteristics, and the addition of the strain score to the model increased the amount of explained variance from 0 to 20 percent ($p < 0.01$). Finally, adding together all three scores of the Wheelchair Circuit at step 3 showed that the performance time score more strongly predicted participation than the ability or physical strain score.

DISCUSSION

In this study, the relationship between wheelchair skill performance and participation was examined. A number of studies have examined participation of persons with SCI [9,13–17,27–29]. In these studies, three different measures of participation were used: SIPSOC [14–15], time spent in productivity and leisure activities [9,13,7,27,29], and the Craig Handicap Assessment and Reporting Technique (CHART) [16–28]. The SIPSOC scores found in the present study (mean = 6.0) correspond well with the mean value of 6.1 found by Dallmeijer and van der Woude [15] and of 7.5 found by Post et al. [14].

The relationship between wheelchair skill performance and participation has, to our knowledge, never been studied. Post et al. found a correlation of 0.42 between the Mobility Control scale and the Social Behavior scale of the SIP68 [21]. In a large study by Whiteneck et al., the Functional Independence Measure (FIM) motor score explained 20 percent of the variance of scores on the CHART, which corresponds to a correlation of 0.45 [30]. Dallmeijer and van der Woude found correlations between –0.39 and –0.51 between physical performance measures

Table 4.
Hierarchical multiple regression analyses of sum of subscales Mobility Range and Social Behavior of 68-Item Sickness Impact Profile (SIPSOC) with demographic variables, lesion characteristics, and scores on Wheelchair Circuit.

Step	Independent Variable	Ability Score (n = 78)		Performance Time Score (n = 73)		Physical Strain Score (n = 47)		All Three Scores (n = 47)	
		β	Adj. R^2	β	Adj. R^2	β	Adj R^2	β	Adj. R^2
1	Age	0.36*	—	0.33†	—	0.34†	—	0.08	—
	Gender	–0.04	—	–0.09	—	–0.08	—	–0.03	—
	Educational Level Medium	–0.04	—	0.001	—	0.21	—	0.26	—
	Educational Level High	0.06	0.12*	0.13	0.13†	0.27	0.01	0.27	0.01
2	Lesion Level	–0.11	—	–0.07	—	–0.05	—	0.09	—
	Motor Completeness	0.18	0.21*	0.18	0.19†	–0.04	0.00	–0.02	0.00
3	Ability Score	–0.33	—	—	—	—	—	–0.16	—
	Performance Time Score	—	—	0.34†	—	—	—	0.45*	—
	Physical Strain Score	—	0.26†	—	0.25†	0.46*	0.20*	0.27	0.34

Note: 1. Only the final regression model is displayed. Gender was coded as 0 = female, 1 = male; lesion level as 0 = tetraplegia, 1 = paraplegia; and motor completeness as 0 = incomplete, 1 = complete.
2. Educational level low to educational medium and high, being the reference of these two variables.
*$p \leq 0.01$
†$p \leq 0.05$

and SIPSOC [15]. The correlations with SIPSOC in our study were in the same range: 0.54 for Performance Time Score, –0.49 for Ability Score, and 0.38 for Physical Strain Score. These results support the validity of results from the Wheelchair Circuit. Also, these figures underscore the relevance of distinguishing the ICF levels of activities and of participation in rehabilitation research [31]. The influence of personal and environmental factors results in not more than moderate correlations between functioning at the levels of activities and of participation, as is shown by these studies [15,21,30–31].

The results of the present study showed that, when demographic variables and lesion characteristics have been considered, a significant proportion of the variance of participation can still be explained by the scores of the Wheelchair Circuit. When the three scores were entered into one multiple regression model, the performance time score was the only score that was still significantly related to participation. However, the subgroup in which this analysis could be performed ($n = 47$) is a positive selection of our total study group. In this subgroup, the ability score clearly showed a ceiling effect with a median score of 7.5 on a 0- to 8-point scale. This finding may explain that the performance time score was more strongly related to participation than to the ability score. The performance time score also overruled the physical strain score. Physical strain was assessed from the maximum heart rates reached during the performance of the 3 and 6 percent slope tests, which were both performed on a treadmill at a belt velocity of 0.56 m/s. This speed is rather slow [29,32–33], which is also illustrated by the relatively low %HRR (interquartile range = 21.5–44.0). In "real life," subjects can freely adjust their speed to the difficulty of the task and thus, to a certain extent, determine their level of physical strain. This might explain why the relationship between the physical strain score and participation is somewhat weaker than the relationship between the performance time score and participation.

The relationship between participation and the performance time score is strong because the performance time score is very realistically related to the ADLs. Frequently in daily life, a person has to sprint a distance at high speed, for instance to catch the bus or to prevent something from burning on the stove.

This study includes some limitations. Because of the cross-sectional design of the present study, a causal relationship between wheelchair skill performance and participation in persons with SCI is impossible to prove. One most likely presumes that good wheelchair skill performance has a positive effect on participation; however, the opposite is also possible. Longitudinal research is required to establish the causality of the relationships found in this study.

To be included into the cohort, persons had to meet several inclusion criteria: age between 18 and 65 years; wheelchair dependent; no progressive disease or psychiatric problem; no cardiovascular problems; and no serious musculoskeletal complaints of the upper-limb, neck, or back. Because of these criteria, our participants are a selection of the complete population of persons with SCI.

The Wheelchair Circuit consists of a selection of all possible wheelchair tasks, and some tasks that may be relevant for participation are not included in this test. However, during the Wheelchair Circuit's development, we found that, clearly, most relevant skills are included in the test, even though they are not separately tested; for example, performing a wheely is not tested, but being able to perform a wheely is conditional to being able to mount the platform.

In this study, users performed the Wheelchair Circuit in a standard wheelchair. We found this was necessary to ensure comparability of the measurements in our main longitudinal study in which persons with SCI are followed from the start of functional rehabilitation to 1 year after discharges [5,34]. Possibly, our participants would have obtained even better scores had they been allowed to use their own wheelchair and the relationship between wheelchair skill and participation may have been even stronger than we found in this study.

All participants who performed the Wheelchair Circuit did have an ability score, and the majority obtained a performance time score, but only those participants who were able to perform both the 3 and 6 percent slope tests and the maximum exercise test obtained a physical strain score. Because of this, the analyses that included the physical strain score concerned a positive selection of the research population, consisting of subjects with a relatively good wheelchair skill performance. This finding is further supported by the fact that the physical strain scores displayed in the present study (mean: 33.5%HRR, **Table 2**) are low compared with those found in other studies. Janssen et al. observed 43 male subjects with longstanding SCI (1–29 years after injury) during a workday and assessed the physical strain induced by several different activities [35]. The mean physical strain recorded during the negotiation of slopes (incline and length not defined, self-selected speed) was just above 40%HRR. In a study of Dallmeijer et al. [36], 18 subjects with SCI ascended a 6 m long slope with a 6 percent incline, at a self-selected speed, 1 year after their discharge from inpatient rehabilitation. The mean physical strain induced by this task was somewhat higher than 40%HRR. Because of these limitations, the generalization of our results may be limited.

CONCLUSION

Manual wheelchair skill performance of persons with SCI is positively associated to participation. During initial rehabilitation, implementing training and therapies to achieve an optimal level of wheelchair skill performance is important. Persons should further be stimulated to maintain their wheelchair skills after discharge from inpatient rehabilitation.

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