Original Article

Health related functional status in men with spinal cord injury: relationship with lesion level and endurance capacity

AJ Dallmeijer^{*,1} and LHV van der Woude¹

¹*Institute for Fundamental and Clinical Human Movement Sciences, Faculty of Human Movement Sciences, Vrije Universiteit Amsterdam, The Netherlands*

Study design: Cross-sectional study.

Objectives: To determine the relationship of health related functional status with lesion level and endurance capacity in persons with spinal cord injury (SCI).

Methods: Thirty-seven men with SCI were divided in four lesion groups: high tetraplegia (motor complete; C5–C6, $n=10$), low tetraplegia (motor complete, C6/7–C8, $n=9$), motor incomplete tetraplegia ($n=7$), and paraplegia ($n=11$). Health related functional status was measured with the short version of the Sickness Impact Profile (SIP68), including a physical (SOM), psychological (PSY) and social subscore (SOC). Endurance capacity, defined as maximal power output ($PO_{\max}$) and peak oxygen uptake ($VO_{2\text{peak}}$), was measured in a maximal exercise test on a wheelchair ergometer.

Results: Total SIP68-score and SOM were significantly different between lesion groups, showing higher values in the high- and low-tetraplegia group. There were no differences between lesion groups for PSY and SOC subscores. $VO_{2\text{peak}}$ and $PO_{\max}$ were significantly higher in the paraplegia group, compared to the high and low tetraplegia groups. $VO_{2\text{peak}}$ was also higher in the motor incomplete *versus* other tetraplegia groups. Significant Spearman correlation coefficients were found for $VO_{2\text{peak}}$ and $PO_{\max}$ with SIP68 and SOM (ranging from -0.68 to -0.79) and SOC (ranging from -0.39 to -0.51). No significant relationship was found with PSY. Hierarchical regression analysis showed that after correction for lesion level, 22% of the variance of SIP68, 8% of the variance of SOM, and 30% of the variance of SOC was explained by $PO_{\max}$ or $VO_{2\text{peak}}$.

Conclusions: Results indicate that there is an evident relationship between the physical dimensions of health related functional status and lesion level, but not for the psychological and social dimensions. After controlling for lesion level a significant amount of the variance of health related functional status can be explained by endurance capacity parameters. Although no causal relationships can be established in this cross-sectional study, these results suggest that functional status may be improved by increasing the endurance capacity.

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Introduction

Several authors have emphasized the importance of physical exercise and sport in persons with spinal cord injuries (SCI) for maintaining or improving adequate physical fitness levels.^{1–6} Some of these authors assumed that higher fitness levels lead to improved daily functioning and health status.² Physical training is therefore also an important part

of the SCI rehabilitation process, which is mainly focused on reaching an optimal level of functional ability and independence. Measures on the level of ability and role fulfilment, the positive counterparts of disability and handicap,⁷ are considered to be most relevant as indicators of rehabilitation outcome. However, physical capacity measures, such as peak oxygen uptake and muscle strength, are measures that are more closely related to the level of function, the positive counterpart of impairment. Although it is assumed that functional abilities will

*Correspondence: AJ Dallmeijer, Faculty of Human Movement Sciences, Vrije Universiteit Amsterdam, Van der Boechorststraat 9, 1081 BT Amsterdam, The Netherlands

enhance as a consequence of improved levels of physical capacity, the relationship between physical capacity and functional abilities has only scarcely been investigated in persons with SCI.^{8–11} The association of measures of physical capacity with functional abilities needs therefore to be established more explicitly.

The effects of rehabilitation and training on physical capacity can be tested under standardized conditions, using wheelchair ergometry or armcrank ergometry tests.⁴ Wheelchair ergometry, such as exercise tests on a treadmill or wheelchair simulator, is a more functional way of testing than armcrank ergometry. As such it is more related to everyday wheelchair ambulation, resulting in higher relevance and validity of the outcome measures.

For evaluating performance at the ability level, several instruments have been developed, like the Functional Independence Measure (FIM), the Barthel Index, and the Sickness Impact Profile (SIP).¹² Although measurements at the ability level are assumed to be more relevant with respect to functioning in daily life, they have in general lower objectivity and reliability than physical capacity measurements.¹³ Hence, evaluating rehabilitation outcomes by measuring physical capacity is much more useful if there is evidence that physical capacity is a determinant of more functional outcome measures. Previous studies revealed significant associations between peak oxygen uptake and the functional ability measured by the Barthel Index and a ADL questionnaire^{8,11} and between shoulder muscle strength and the FIM-score.¹⁰ Other studies showed that improvements in physical capacity were associated with lower levels of physical strain during activities of daily living,^{9,14} which in turn may lead to greater functional independence. However, evidence is scarce and may depend on the instrument used for measuring functional outcome. Furthermore, in most of these studies lesion level was not taken into account, despite the fact that lesion level is an important determinant of physical fitness.²

The Sickness Impact Profile (SIP) is an instrument for measuring health-related functional status at the level of disability and handicap and has been widely used and evaluated.¹² Physical, psychological and social aspects of functional status are measured by assessing the behavioural impact of sickness. A shorter version of the SIP (SIP68) has been developed in a multi diagnostic sample in The Netherlands¹⁵ which has been proven reliable and valid in a population of 315 subjects with SCI and has been recommended for use in rehabilitation medicine.¹⁶

The purpose of the present study was to determine the relationship of the SIP68 scores with lesion level and endurance capacity, defined as peak oxygen uptake and maximal power output, measured during wheelchair ergometry in a group of men with different levels of SCI.

Methods

Subjects and procedure

Thirty-seven men with SCI participated in this study after having given their written informed consent. The group was divided in four lesion groups; subjects with a motor complete tetraplegia at C5–C6 (TP-high, $n=10$), subjects with a motor complete tetraplegia at C6/7–C8 (TP-low, $n=9$), subjects with a motor incomplete tetraplegia (TP-inc, $n=7$), and subjects with a paraplegia (PP, Th1–L4, $n=11$, including two subjects with a motor incomplete paraplegia). Subjects with ASIA impairment score¹⁷ A and B were categorized as motor complete, and subjects with ASIA impairment score C and D as motor incomplete. Classification of lesion level was performed according to the international standards.¹⁷ Subjects with a C6 classification on one side and a C7 classification on the contralateral side were classified as C6/7 and included in the TP-low group. Subjects with cardiovascular complications and injuries of the musculoskeletal system of the upper extremity were excluded from the study. All subjects were participants of two previous studies.^{14,18}

To investigate the relationship between health related functional status, lesion level and endurance capacity, all subjects performed a maximal wheelchair exercise test in the laboratory and were asked to fill out the SIP68 questionnaire.

SIP68

The Sickness Impact Profile (SIP) is a questionnaire that measures health related functional status by assessing the impact of sickness on behaviour.¹⁵ The Dutch SIP68 is a short version of the original SIP, containing 68 items instead of the original 136 items, and was proven to be valid and reliable for use in persons with SCI.¹⁶ The 68 items are divided over six subscales; somatic autonomy (SA), mobility control (MC), psychic autonomy and communication (PAC), emotional stability (ES), social behaviour (SB), and mobility range (MR). Physical (SOM), psychological (PSY) and social (SOC) dimensions of functional status were defined according to Post *et al*¹⁹ as the sum of SA and MC (SOM), PAC and ES (PSY), and SB and MR (SOC), respectively. SOM and PSY are considered as outcome measures at the disability level, whereas SOC is considered as an outcome measure at the level of handicap. Subjects were asked to indicate whether an item applied to their situation. A higher score indicates more health related problems.

As recommended in the SIP68 guidelines²⁰ the adaptation in scoring procedure for wheelchair users was used; in case the SA item 'I do not walk at all' was scored by the subjects, all seven MC items related to walking were also considered as being scored. The SIP68 questionnaire was filled out by 18 subjects during their visit to the laboratory. Twenty-one subjects received the questionnaire at home by mail.

Two subjects did not return the questionnaire and were excluded from the study.

Endurance capacity

To determine endurance capacity, maximal power output ($PO_{\max}$) and peak oxygen uptake ($VO_{2\text{peak}}$) were measured in a maximal incremental exercise test on a computer controlled wheelchair ergometer.²¹ The test consisted of 1-min exercise bouts. Resistance was individually adjusted, based on the estimated maximal power output, which was calculated as described by Dallmeijer *et al*¹⁸. Starting off with an exercise level of 20% of the estimated maximal power output, resistance was increased by 10% each minute. Velocity was kept constant at 0.83 or 1.11 m·s⁻¹, depending on lesion level. The test was terminated when the subjects could no longer maintain the required velocity because of exhaustion. Hand rim torque (M [Nm]) around the wheel axle and linear velocity of the wheel (v [m·s⁻¹]) were measured during the last 10 s of each exercise bout. Power output was calculated according to:

$$PO = M \cdot v \cdot r_w^{-1} \quad (1)$$

where r_w is the wheel radius (=0.31 m). $PO_{\max}$ was defined as the highest power output averaged over the last 10 s of each exercise bout. Oxygen uptake was measured during the test using an Oxycon Ox4 (Jaeger, Bunnik, The Netherlands). Calibration was performed before each test using reference gases. The highest average value over 60 s was defined as the $VO_{2\text{peak}}$.

Statistics

One-way analysis of variance was applied to determine significant differences among lesion groups for subject characteristics, $VO_{2\text{peak}}$ and $PO_{\max}$. A Tukey *post-hoc* analysis was applied to establish differences between groups. Non-parametric statistics (Kruskal-Wallis test for more than two independent samples) was used to determine differences among lesion groups for total SIP68-scores as well as for SOM, PSY and SOC. Differences between groups were determined by performing pairwise comparison using a Bonferroni adjustment.²² Spearman's rank correlation coefficients were calculated to investigate the relationship between the SIP68 scores and endurance capacity parameters ($VO_{2\text{peak}}$ and $PO_{\max}$). To investigate the SIP68 outcome in association with endurance capacity, while controlling for lesion level and completeness of the lesion, a hierarchical regression analysis was applied. Total SIP68-score, SOM, PSY and SOC were used as dependent variables. After including lesion level (C5–C6: 1, C6/7–C8: 2, paraplegia: 3) and completeness of the lesion (incomplete: 0, complete: 1) in the regression equation, $VO_{2\text{peak}}$ or $PO_{\max}$ was added to the equation in order to investigate whether an additional proportion of the variance in SIP scores

was explained by $VO_{2\text{peak}}$ or $PO_{\max}$. Level of significance was set at $P < 0.05$.

Results

Subjects

Subject characteristics for each lesion group are listed in Table 1. Age of the subjects was between 18 and 67 years. Times since injury ranged from 1 to 32 years. Groups were different with respect to age, with a lower age in TP-high compared to TP-low. Body mass and time since injury were not different between groups.

SIP68

Results for the total SIP68-score and each sub-scale are shown in Figure 1. Mean total SIP68-score was 23.2 (± 9.3) for the whole group. Physical (SOM), psychological (PSY) and social (SOC) sub-scores were 15.5 (± 5.7), 1.6 (± 2.5), and 6.1 (± 4.3), for the whole group, respectively. Total SIP68 and SOM subscore showed significantly higher values in TP-high and TP-low, in comparison to TP-inc and PP (except for the SIP68-score between TP-low and TP-inc). No differences were found between lesion groups for the PSY and SOC subscores.

Endurance capacity

Results of the maximal exercise test are shown in Figure 2. $VO_{2\text{peak}}$ was significantly lower in TP-high, in comparison to TP-inc and PP. The TP-low group showed also a significantly lower value for $VO_{2\text{peak}}$ compared to PP. For $PO_{\max}$, values were significantly lower in TP-high, TP-low and TP-inc *versus* the PP group. $PO_{\max}$ and $VO_{2\text{peak}}$ values expressed per kg body mass revealed the same results.

Table 1 Subject characteristics ($n = 37$)

	Age	TSI	Body mass
TP-high	26.3	4.1	74.1
C5–C5 ($n = 10$)	(7.4)	(2.1)	(21.2)
TP-low	45.9 ^a	8.4	81.1
C6/7–C8 ($n = 9$)	(12.5)	(10.4)	(15.5)
TP-inc ($n = 7$)	35.7	2.9	74.1
	(13.7)	(1.0)	(14.8)
PP ($n = 11$)	38.5	2.0	81.6
Th1–L4	(15.0)	(0.4)	(12.6)
Total group ($n = 37$)	36.5	4.3	78.0
	(13.9)	(5.6)	(16.1)
<i>P</i> -value	0.015	0.068	0.620

^a: significantly different from TP-high

Figure 1 SIP68-scores by lesion group. Bars represent mean values, error bars represent standard deviations. (a) significantly different from TP-high, (b) significantly different from TP-low, TP-high: C5–C6; TP-low: C6/7–C8; TP-inc: motor incomplete tetraplegia; PP: Th1–L4. SIP68: total SIP68-score; SOM: physical dimension; PSY: psychological dimension; SOC: social dimension

Figure 2 Endurance capacity (maximal power output: PO_{max}, peak oxygen uptake: VO_{2peak}) for each lesion group. Bars represent mean values, error bars represent standard deviations. (a) significantly different from TP-high, (b) significantly different from TP-low, (c) significantly different from TP-inc. TP-high: C5–C6; TP-low: C6/7–C8; TP-inc: motor incomplete tetraplegia; PP: Th1–L4

Relationship between SIP68-scores, lesion level and endurance capacity

Spearman's rank correlation coefficients between SIP68-scores and endurance capacity are shown in Table 2. Significant inverse correlation coefficients were found between total SIP68-score and PO_{max} ($r = -0.68$) and VO_{2peak} ($r = -0.74$), and between

Table 2 Spearman correlation coefficients for SIP68 scores with endurance capacity ($n = 37$)

	PO _{max} (W)	PO _{max} /kg (W·kg ⁻¹)	VO _{2peak} (l·min ⁻¹)	VO _{2peak} /kg (ml·kg ⁻¹ ·min ⁻¹)
SIP68	−0.68***	−0.68***	−0.74***	−0.71***
SOM	−0.75***	−0.74***	−0.79***	−0.71***
PSY	−0.10	−0.10	−0.13	−0.14
SOC	−0.39*	−0.41*	−0.43**	−0.51**

***: $P < 0.001$; **: $P < 0.01$; *: $P < 0.05$

SOM and PO_{max} ($r = -0.75$) and VO_{2peak} ($r = -0.79$). Lower but also significant correlations were found between SOC and PO_{max} ($r = -0.39$) and VO_{2peak} ($r = -0.43$). PSY was not significantly related to endurance capacity.

Results of the hierarchical regression analysis are listed in Table 3. Results show that lesion level and completeness of the lesion explained 28% of the variance of SIP68 and 71% of the variance of SOM. There was no significant relationship between lesion level and completeness of the lesion for PSY and SOC. Adding PO_{max} to the regression equation of SIP68 showed that an additional 23% of variance of SIP68 could be explained by PO_{max} ($P < 0.001$ for r^2 -change). An additional 8% of the variance of SOM was significantly explained by VO_{2peak} ($P < 0.001$), and 30% of the variance of SOC was explained by PO_{max} ($P < 0.001$). Lesion level, completeness of the lesion, and endurance capacity explained in total 51%, 79%, and 31% of the variance of SIP68, SOM, and SOC, respectively. No significant relationship could be established for PSY.

Discussion

The aim of this cross-sectional study was to investigate the association between health related functional status, lesion level and endurance capacity in persons with different levels of SCI. As expected, total SIP68 and the physical subscore differed considerably between lesion groups, showing higher values in the motor complete tetraplegia groups. Results of the hierarchical regression analysis showed that, although lesion level is an important determinant of health related functional status, endurance capacity parameters explain an additional proportion of the variance of health related functional status.

SIP68 and endurance capacity in relation to lesion level

The significant differences between lesion groups for total SIP68 and SOM scores, with higher values in the motor complete tetraplegia groups compared to the paraplegic and motor incomplete tetraplegia groups, are in agreement with the results of Post *et al.*¹⁹ They also found a significant relationship between physical SIP68 scores and type of injury. For the physical dimension of the SIP68 Post *et al.* found 20.7

Table 3 Results of a hierarchical multiple regression analysis ($n=37$), using as independent variables: lesion group (TP-high: 1, TP-low: 2, PP: 3), completeness of the lesion (incomplete: 0, complete: 1), and endurance capacity (VO_{2peak} or PO_{max}). SIP68: total SIP68-score; SOM: physical dimension; PSY: psychological dimension; SOC: social dimension

Dependent variables	Independent variables	Regression coefficients	P-value	r^2
SIP68	Constant	22.6	0.000	
	Lesion group	2.5	0.268	0.11
	Completeness	7.1	0.012	0.28
	PO_{max}	-0.27	0.001	0.51
SOM	Constant	18.4	0.000	
	Lesion group	-2.4	0.001	0.26
	Completeness	7.9	0.000	0.71
	VO_{2peak}	-4.2	0.001	0.79
PSY	Constant	0.75	0.559	
	Lesion group	0.90	0.286	0.00
	Completeness	0.43	0.671	0.01
	PO_{max}	0.003	0.215	0.06
SOC	Constant	6.1	0.002	
	Lesion group	3.3	0.011	0.00
	Completeness	-1.59	0.288	0.01
	PO_{max}	-0.14	0.001	0.31

and 13.7 for complete tetraplegia and paraplegia groups, and 11.8 and 8.2 for incomplete tetraplegia and paraplegia groups, respectively. These values do agree well with the findings of the current study for the complete tetraplegia (21.7 and 17.1), incomplete tetraplegia (10.9), and paraplegia (11.5) group. A reduced functional ability with greater neurological impairment was also reported in studies investigating the relationship between FIM scores and lesion level in persons with SCI.²³⁻²⁵

There were no differences between lesion groups for the social and psychological dimensions in the present study. On the contrary, Post *et al*¹⁹ found a weak but significant relationship for both dimensions in a much larger subject group ($n=318$). However, it may be concluded from these results that lesion level is mainly affecting the physical dimension and is of limited influence on the social and psychological dimension of health related functional status.

From Figure 2 it appears that PO_{max} and VO_{2peak} are strongly dependent on lesion level. A higher level of injury means a smaller active muscle mass, which will in turn result in a reduced endurance capacity. The lower values for the maximal power output and oxygen uptake in the motor complete tetraplegia groups are in accordance with several previous studies, which reported that endurance capacity is strongly determined by the primary impairment (ie the level of the lesion).^{4,26,27}

The variability within lesion groups was considerable for all investigated SIP68 dimensions. Next to the influence of other personal characteristics, this large

variability seems to be the consequence of the heterogeneity in lesion level within the lesion groups. Defining appropriate, homogenous subject groups based on neurological level of injury has also been a problem in previous research.^{10,24} As suggested by Ota *et al*,²⁴ the use of the ASIA motor score in future studies will better reflect the primary impairment than the usually reported neurological level.²⁴

The significant differences in VO_{2peak} and physical dimension between the motor incomplete and complete tetraplegia groups, and the considerable effect of completeness of the lesion in the regression analysis, indicate that completeness of the lesion should be taken into account when investigating physical fitness or functional ability. Post *et al*¹⁹ also found that lesion level and completeness of the lesion were the most important determinants of the physical SIP68-score.

SIP68 in relation to endurance capacity

The significant correlation coefficients between the SIP68-scores and measures of endurance capacity indicate that a higher endurance capacity is associated with a better functional status. This implies that functional abilities may be improved by increasing endurance capacity. However, because we know that lesion level is an important predictor of endurance capacity, a hierarchical regression analysis was applied to correct for the effect of lesion level. Results of this analysis showed that, when lesion level has been taken into account, still a significant proportion of the variance of health related functional status can be explained by endurance capacity (PO_{max} and VO_{2peak}). Training and physical activity have been shown to improve the endurance capacity considerably in persons with SCI,² thus leaving the possibility for improving physical abilities, despite the level of injury.

These results are in agreement with previous results of Noreau *et al*,⁸ who found fair correlations between peak oxygen uptake, muscular strength and functional ability, measured with the Modified Barthel Index. They found a more pronounced relationship in persons with tetraplegia in comparison with those with paraplegia. In the present study it was not possible to differentiate between lesion groups for the reported associations because of the smaller subject groups. Another study also reported an increase in functional ability with higher values for peak oxygen uptake.¹¹ However, in that study lesion level was not taken into account. Fujiwara *et al*¹⁰ also found a significant relationship between shoulder muscle strength and functional ability measured with the FIM in C6 tetraplegic patients. To our knowledge no relationships between maximal power output and functional outcome measures have been determined yet.

In contrast to the lack of relationship between lesion level and the social dimension, endurance capacity explained an unexpected large proportion of the variance of the social subscore. However in the current study no corrections were made for other

possible predictors of the social dimension, such as age and other personal characteristics.¹⁹ Nevertheless, the results suggest an influence of endurance capacity on social functioning. In contrast, there was no significant relationship between the psychological subscore and lesion level and/or endurance capacity. Psychological functioning is probably more influenced by other factors, not investigated in this study, such as health problems.¹⁹

Conclusions of the present study are limited by the cross-sectional character of the study and the relatively small number of subjects. Even though it is highly likely that a higher endurance capacity results in better functional abilities, it may also be possible that persons with higher abilities are more able to maintain appropriate fitness levels. Moreover, to what extent the endurance capacity should be improved in order to gain functional effects, remains to be investigated in controlled training studies.

Results indicate that there is an evident relationship between the physical dimensions of health related functional status and lesion level, but not for the psychological and social dimensions. After controlling for lesion level some (significant) amount of the variance of health related functional status can be explained by endurance capacity parameters. Although no causal relationships can be established in this cross-sectional study, these results suggest that functional status may be improved by increasing the endurance capacity, underlining the relevance of endurance capacity parameters with respect to functional status. The findings emphasize that improving endurance capacity by regular training and an active lifestyle may have positive effects on functional abilities, and should therefore be encouraged in rehabilitation and daily life of wheelchair users with SCI.

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