Longitudinal relationship between wheelchair exercise capacity and life satisfaction in patients with spinal cord injury: A cohort study in the Netherlands

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Objective: To examine the relationship between wheelchair exercise capacity and life satisfaction in persons with spinal cord injury from the start of active inpatient rehabilitation up to 5 years after discharge.

Design: Prospective cohort study.

Subjects: Persons with spinal cord injury, aged 18–65 years, and wheelchair dependent at least for long distances.

Method: Measurements at the start of active rehabilitation, after 3 months, at discharge from inpatient rehabilitation, and 1 and 5 years after discharge. A peak wheelchair exercise test was performed to record peak oxygen uptake (VO_{2peak}) and peak power output (PO_{peak}). Life satisfaction was measured as current life satisfaction and change of life satisfaction in comparison with life after spinal cord injury. Relationships between (changes in) exercise capacity and (changes in) life satisfaction were analyzed random coefficient analysis, corrected for possible confounders (age, gender, level of lesion, functional status, secondary impairments, pain, and sports activity) if necessary.

Results: Of 225 persons included, 130 attended two or more peak exercise tests, who were included in the analyses. Mean age at start was 39 years, 75% were male, 73% had paraplegia, and 76% had a traumatic lesion. Mean PO_{peak} increased during the study from 32.9 to 55.9 Watts, mean VO_{2peak} from 1.02 to 1.38 l/minute, and mean life satisfaction from 5.7 to 7.8. An increase of PO_{peak} with 10 W was associated with a 0.3-point increase of life satisfaction ($P = 0.01$). An increase of VO_{2peak} with 0.1 l/minute was associated with a 0.1-point increase of life satisfaction ($P = 0.049$).

Conclusion: High(er) wheelchair exercise capacity is related to high(er) life satisfaction in spinal cord injury patients.

Keywords: Life satisfaction, Physical fitness, Spinal cord injury, Longitudinal, Cohort

Introduction

In the 1940s, Sir Ludwig Guttmann was the first to introduce sport and exercise therapy as part of rehabilitation following spinal cord injury (SCI).¹ Initiated research studied the effects of physical exercise on

patients with SCI, primarily with respect to physiological changes and benefits.^{2–5} In addition to the physiological benefits of exercise, the benefits of exercise on quality of life have been reported in the general population.⁶ Positive relationship between the broad constructs of physical activity and quality of life, has been repeatedly published,^{7–15} although some authors report conflicting results.^{16,17} A meta-analysis on

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physical activity and life satisfaction reported a small- to medium-sized positive relationship in persons with SCI.¹⁸ This relation is reportedly due to the intermediate effects of physical activity on feelings of self-worth, self-efficacy, personal control, and enhanced social interaction; these effects foster community integration and influence life satisfaction. However, most studies are cross-sectional and include healthy, young, active male patients who have lived with their injuries for a long time. Moreover, authors use different definitions of physical activity and often the focus was on the indirect effects of physical activity on life satisfaction. No published study focuses on the specific relationship between wheelchair exercise capacity and life satisfaction in patients with SCI.

Wheelchair exercise capacity, as measured using standardized tests, is the most objective measure of physical fitness (ICF Domain Body Structure & Function)¹⁹ and covers a different entity than the subjective measurements of physical activity (ICF domain Activities and Participation).¹⁹ High wheelchair exercise capacity is associated with better long-term health status in patients with SCI,²⁰ decreased risk of complications,^{2,21} and a better physical activity profile,⁴ all of which potentially influence life satisfaction.²²

Life satisfaction is the cognitive component of subjective well-being.²³ Life satisfaction is a multifaceted entity that is widely studied in SCI patients and is increasingly considered an important outcome measure in rehabilitation medicine.^{23–25}

Our earlier studies report that life satisfaction and wheelchair exercise capacity recover over time.^{26–29} Knowledge of the longitudinal association between wheelchair exercise capacity and life satisfaction may help to improve (1) physical and mental adaptation to SCI over time and (2) intervention programs, in- and outpatient rehabilitation, and follow-up care.

The aim of this study is to investigate the longitudinal relationship between wheelchair exercise capacity and life satisfaction in a prospective cohort in the Netherlands. This study was carried out from the start of inpatient SCI rehabilitation through 5 years after discharge. Our hypothesis was that SCI patients with high wheelchair exercise capacity would demonstrate high life satisfaction.

Methods

Participants

This study is part of the Dutch research program “Physical strain, work capacity and mechanisms of restoration of mobility in the rehabilitation of individuals with a SCI”³⁰ with focus on the development over time

of wheelchair exercise capacity and life satisfaction.^{26–29} Eight rehabilitation centers specialized in SCI participated in the project. Subjects were eligible to enter the project if they had an acute SCI; were between 18 and 65 years of age; were classified as A, B, C, or D on the American Spinal Injury Association Impairment Scale³¹ and were expected to remain wheelchair dependent, at least for long distances. Exclusion criteria were SCI due to malignancies, progressive disease, known cardiovascular disease, or psychiatric problems; insufficient command of the Dutch language to understand the goal of the study and the testing methods. The Medical Ethics Committee of the Stichting Revalidatie Limburg/Institute for Rehabilitation Research in Hoensbroek and all local Medical Ethics Committees approved the research-protocol in 1999 and The Medical Ethics Committee of the University Medical Center of Utrecht approved the sequel research-protocol in 2006. All subjects gave written informed consent. Data were collected from 1999 until 2009.

Procedure

Measurements were performed at the start of active rehabilitation (start, defined as the moment that a person could sit for 3–4 hours), 3 months after start, at discharge from inpatient rehabilitation, 1 year after discharge and 5 years after discharge. The measurement at 3 months after start of active rehabilitation was performed only if inpatient rehabilitation took longer than 3 months. These five measurement occasions comprised a medical anamnesis and physical examination by a rehabilitation physician, an oral interview with a trained research assistant, a self-report questionnaire, and physical tests among which a peak wheelchair exercise test.

Instruments

Demographic characteristics were collected at the first measurement and included age and sex.

Lesion characteristics were assessed according to the International Standards for Neurological Classification of Spinal Cord Injury.³¹ The ASIA Impairment Scale classifications A and B were considered motor complete and the classifications C and D were considered motor incomplete. Neurological lesion level was defined as the highest motor level. Neurological levels below T1 were defined as paraplegia and neurological lesion levels at or above T1 were defined as tetraplegia. Cause of injury was categorized as traumatic versus non-traumatic.

Functional independence was measured with the motor score of the Functional Independence Measure,

consisting of 13 items about self-care, mobility, transfers, and toileting.³² We divided the sum score into a group with low scores, 0–74 points (low functional status = 0) and a group with high scores 75–91 points (high functional status = 1).

Secondary impairments were grouped into three categories:

Musculoskeletal pain

Inquiries were made about 13 locations of musculoskeletal pain. All were scored as “absent = 0” or “present = 1” during the previous 12 months. A total Musculoskeletal Pain score was computed as the sum score of all items (range: 0–13) and the scores were divided into one group with 0 to 1 complaints (low pain = 1) and one group with two or more complaints (high pain = 0).

Neuropathic pain

One item was included about pain other than musculoskeletal pain, along with eight other abnormal sensations such as numbness, tingling, burning, phantom, hot or cold feelings, itching and dull feelings. All were scored as “absent = 0” or “present = 1” during the prior 12 months. A total Neuropathic Pain score was calculated as the sum score of all items (range: 0–9) and the scores were divided into one group with 0–2 complaints (low pain = 1) and one group with 3 or more complaints (high pain = 0).

Other secondary impairments

Seven items, including pressure sores, urinary tract infections, pulmonary infections, neurogenic heterotopic ossification, oedema, hypotension, and autonomic dysreflexia, were scored as “absent = 0” or “present = 1” during the previous 12 months. A total score was computed as the sum score of all items (range: 0–7) and the total scores were divided into one group with 0 to 1 impairments (low impairments = 1) and one group with 2 or more impairments (high impairments = 0).

Sports participation

The time spent on sports activities was recorded in hours per week at the measurement occasions at one and five years after discharge of inpatient rehabilitation. This item is part of the Utrecht Activities List.³³ This score was divided into a group with 0–1 hours sports per week (low sports participation = 0) and a group with more than 1 hour (range 1.1–40) sports per week (high sports participation = 1).

All cut-off points in dividing procedures were chosen to create more or less even numbers of persons reporting low and high figures of the potential confounders.

Determinant

Wheelchair exercise capacity is defined as the combined ability of the cardiovascular, the respiratory and the musculoskeletal systems to attain a certain level of activity in a wheelchair.²¹ Subjects performed a peak maximal wheelchair exercise test on a motor-driven treadmill. The testing protocol and equipment have been described elsewhere.^{22,26,27,34} VO_{2peak} was defined as the highest value of oxygen consumption recorded during 30 seconds. PO_{peak} was defined as the power output at the highest inclination that the subject could maintain for at least 30 seconds.

Outcome measure

Life satisfaction is defined as the cognitive component of subjective well-being.^{23,24,28,29} *Measurements of life satisfaction* was part of the oral interview. We used two questions to measure life satisfaction, the LS Questions³⁵:

Life Satisfaction Now (LS Now) was phrased: People can be more or less satisfied with their life as a whole, their so called ‘quality of life’. What is your quality of life at the moment? Response categories were very unsatisfying (1), unsatisfying (2), rather unsatisfying (3), rather satisfying (4), satisfying (5), and very satisfying (6).

Life Satisfaction Comparison (LS Comparison) was phrased: When you compare your life now with your life shortly before the SCI; is your quality of life now worse, equal or better than before the SCI? Response categories were much worse (1), worse (2), somewhat worse (3), about the same (4), somewhat better (5), better (6), and much better (7).

Supported by correlations (Pearson’s $r = 0.5–0.6$)^{23, 31} between both scores at all measurements, a sum score of both questions, *Life Satisfaction Total (LS Total)*, was computed. This LS total score was normally distributed at each measurement (skewness 0.0–0.5). The LS Questions was validated for SCI by Post *et al.*³⁵

Statistics

Descriptive statistics were calculated with SPSS 18.0 (SPSS, Inc., Chicago, IL, USA). Data are presented in means and standard deviations, unless otherwise stated.

Random coefficient analysis, also known as mixed effects model analysis, was used to study the course of life satisfaction and its relationship with the independent variables PO_{peak} and VO_{2peak} .³⁶ We performed analyses for PO_{peak} and VO_{2peak} separately because of the strong inter-correlation between both variables. Included in these analyses were subjects who performed two or more out of five peak exercise tests during the test period. In order to describe possible consequences of

this selection on the study outcomes, we compared the included and excluded subjects on available personal and lesion characteristics and on life satisfaction at all occasions using *t*-tests and χ^2 tests ($P < 0.05$).

Two different random coefficient models were computed: a standard model based on values at each test occasion (standard model) and a model based on change scores (change model). This latter model was added, because in the standard model, the regression coefficients reflect a combination of the within-subject variance (longitudinal relationship) and the between-subjects variance (cross-sectional relationship) between wheelchair exercise capacity and life satisfaction, whereas the regression coefficients in the change model only reflect the within-subjects variance. If the results of the standard model and the change model show similar relationships, the association between determinant and life satisfaction is mainly based on within-subject variance. If not, the association is mainly based on between-subjects variance.

In the standard model, life satisfaction total was used as the dependent variable. Time was included in the basic model as a set of four dummy variables, representing active inpatient rehabilitation (start-discharge), the last part of active inpatient rehabilitation (3M-discharge), the short-term period after inpatient rehabilitation (discharge-1Y), and the long-term period after discharge of inpatient rehabilitation (discharge-5Y). The assessment of life satisfaction at discharge was chosen as the reference measurement and was estimated by the intercept. Estimates of life satisfaction at the other measurement times were obtained by adding the regression coefficients of the time dummies to the intercept. The independent variables PO_{peak} and VO_{2peak} and their interactions with time were added separately to the basic model to study their individual relationship with the life satisfaction total scores.

The possible confounding effect of the variables age, sex, level of lesion, completeness of lesion, functional status, secondary impairments, musculoskeletal pain, neuropathic pain, and sports activity at 5 years after discharge on the relationship between the independent variables PO_{peak} and VO_{2peak} and the life satisfaction total scores were studied. The possible confounders were added separately to the basic model. A variable was considered a confounder if the Beta of the independent variable PO_{peak} and VO_{2peak} changed more than 10% after adding one of these variables to the model.³⁶ Ultimately, by entering all time interaction terms, adding PO_{peak} or VO_{2peak} and their time interaction terms separately and including the significant confounders, two final random coefficient models were

built to determine the course of wheelchair exercise capacity in relation to life satisfaction.

In the change model, a change in life satisfaction total for every time interval between the successive measurements was used as the dependent variable. Change scores for the independent variables PO_{peak} and VO_{2peak} were added, to study their bivariate relationship with the change in life satisfaction total. The possible confounders were added separately again to the model, in the same way as the standard model. Separate models for PO_{peak} and VO_{2peak} were built.

Results

Respondent characteristics

At the start of active rehabilitation, 225 persons with SCI were included in the study. At 5 years after discharge, 146 persons of this group participated in the measurement. During the follow-up period, 30 persons died, 17 refused to collaborate, 5 moved, 10 were untraceable, and the rest had other reasons for not participating. A total of 130 persons were able or willing to perform two out of five wheelchair exercise tests and were included in analyses (participants).

Characteristics of the participants and the non-participants are displayed in Table 1. Included patients were on average younger and had more often paraplegia than non-participants. Life satisfaction scores were significantly lower for non-participants patients at all occasions. (Only the figures at the start of active rehabilitation and 5 years after discharge are presented.)

Descriptive data of life satisfaction, wheelchair exercise capacity (PO_{peak} and VO_{2peak}), and possible time-dependent confounders are presented in Table 2.

Relations between wheelchair exercise capacity and life satisfaction

Both PO_{peak} and VO_{2peak} were significantly associated with life satisfaction total in both the basic models and the models after correction for confounders (Tables 3 and 4). There were no significant interactions of PO_{peak} and VO_{2peak} with time. Confounders were sex, level of lesion, functional status and sports participation. Neuropathic pain was a confounder for PO_{peak} only and completeness of injury for VO_{2peak} only in relation to life satisfaction total. The regression coefficients in the table represent the change in outcome associated with an increase in the independent variable PO_{peak} or VO_{2peak} of 1 unit. After correction for confounders, a 10-W higher PO_{peak} score was associated with a 0.34 higher life satisfaction total score. A higher score of 0.1 l/minute VO_{2peak} was associated with a 0.12 higher life satisfaction total score (Table 4).

Table 1 Participant and lesion characteristics and life satisfaction scores for study group and non-participants

Characteristics		Participants (n = 130)		Non-participants (n = 95)	
Male (%)		97	(74.6)	71	(74.2)
Age (years) (SD)		38.7	(13.7)	44.1*	(13.9)
AIS Impairment Scale (%)	A	74	(56.9)	36*	(37.9)
	B	18	(13.8)	29*	(30.5)
	C	14	(10.8)	14	(14.7)
	D	24	(18.5)	15	(15.7)
Paraplegic lesion (%)		96	(72.1)	40*	(42.3)
Tetraplegic lesion (%)		23	(17.9)	55	(57.7)
Motor completeness of injury (%)		89	(68.5)	69	(72.6)
Traumatic cause of injury (%)		99	(76.0)	65	(69.0)
Length of rehab in days (SD)		248.1	(132.3)	265.1	(150.8)
Life satisfaction (SD) Start		5.7	(2.2)	4.9*	(2.3)
Life satisfaction (SD) 5Y		(n = 100) 7.8	(2.4)	(n = 41) 6.7*	(2.6)

Data represent n (%) and mean (SD).

Start= start of active rehabilitation; Study group = total study group with 2 or more exercise measurements during follow up; non participants = loss to follow up in peak wheelchair exercise test during follow up.

*Significant difference with $P < 0.05$ between study group and non participants.

Table 2 Descriptive data of life satisfaction, wheelchair exercise capacity (PO_{peak} and VO_{2peak}) and time-dependent confounders (mean, SD) for study group (n = 130). N = numbers of participants of the study group at the different measurement occasions

	Maximum range	Start N = 129	3 M N = 92	Discharge N = 126	1Y N = 107	5Y N = 100
Life satisfaction	2–13	5.7 (2.2)	6.3 (2.4)	6.8 (2.3)	6.9 (2.1)	7.8 (2.4)
PO_{peak} (W)	3.4–134.4	32.9 (17.0)	41.6 (20.8)	44.6 (22.0)	50.2 (26.1)	55.9 (27.2)
VO_{2peak} (l/minute)	0.33–2.96	1.02 (0.3)	1.14 (0.4)	1.21 (0.4)	1.27 (0.4)	1.38 (0.5)
FIM	13–91	46.8 (17.8)	61.6 (20.4)	72.8 (15.7)	67.2 (16.5)	68.6 (17.9)
Secondary impairments	0–7	1.3 (1.2)	1.6 (1.1)	1.1 (1.1)	1.5 (1.3)	1.7 (1.4)
Musculoskeletal pain	0–13	2.1 (2.0)	1.7 (1.5)	1.4 (1.5)	1.5 (1.9)	2.8 (2.8)
Neuropathic pain	0–9	3.0 (1.8)	4.0 (1.6)	2.4 (1.6)	2.6 (1.6)	2.9 (2.2)
Sports participation (hours)	0–40	3.9 (5.6)*	—	—	2.4 (3.8)	3.9 (6.0)

Data represent means (SD).

Study group = total study group with 2 or more exercise measurements during follow up; Start= start of active rehabilitation; 3M = 3 months after Start; Discharge= discharge of active rehabilitation; 1Y = one year after discharge; 5Y = 5 years after discharge. FIM, Functional Independence Measurement; PO_{peak} , peak Power Output; VO_{2peak} , peak maximal oxygen intake.

*Sports participation before onset of SCI.

Table 3 The longitudinal relation between wheelchair exercise capacity (PO_{peak} and VO_{2peak}) and life satisfaction: basic random coefficient model

Independent variable	Model 1 with PO_{peak} as determinant			Model 2 with VO_{2peak} as determinant		
	Beta	SE	P	Beta	SE	P
Constant (reference discharge)	6.019	0.300		5.925	0.383	
Δ Discharge – Start	–1.042	0.311	0.001*	–1.211	0.313	0.000*
Δ Discharge – 3M	–0.538	0.326	0.099	–0.634	0.326	0.052
Δ Discharge – 1Y	0.076	0.319	0.812	0.057	0.320	0.859
Δ Discharge – 5Y	0.894	0.358	0.013*	0.811	0.363	0.026*
PO_{peak} (W)	0.019	0.005	0.000*	NE	NE	
VO_{2peak} (l/minute)	NE	NE		0.863	0.363	0.018*

All results are unstandardized regression coefficients (β) and unstandardized standard errors (SE) for the regression model (constant + time dummy + determinant). The regression coefficients represent the change in outcome associated with an increase in the independent variable of 1 unit.

Start= start of active inpatient rehabilitation; 3M = 3 months after start; discharge= discharge of inpatient rehabilitation; 1Y and 5Y = respectively 1 and 5 years after discharge of inpatient rehabilitation. PO_{peak} , peak Power Output; VO_{2peak} , peak maximal oxygen intake; NE, not entered.

*Significant with $P < 0.05$.

Δ = the time interval.

Table 4 The longitudinal relation between wheelchair exercise capacity (PO_{peak} and VO_{2peak}) and life satisfaction: final random coefficient model

Independent variable	Model with PO _{peak} as determinant			Model with VO _{2peak} as determinant		
	Beta	SE	P	Beta	SE	P
Constant (reference discharge)	5.985	0.414		5.411	0.509	
Δ Discharge – Start	−0.499	0.378	0.187	−0.810	0.400	0.043
Δ Discharge – 3M	−0.900	0.589	0.114	−0.381	0.376	0.312
Δ Discharge – 1Y	0.249	0.355	0.484	0.200	0.370	0.589
Δ Discharge – 5Y	0.910	0.376	0.016	0.885	0.392	0.024
PO _{peak} (W)	0.034	0.008	0.000*	NE	NE	
VO _{2peak} (l/minute)	NE	NE		1.174	0.403	0.000*
<i>Confounders</i>						
Sex [†]	−0.990	0.313	0.002	−0.826	0.313	0.008
Level of lesion [‡]	−0.851	0.363	0.019	−0.044	0.341	0.897
NP Pain [¶]	0.458	0.254	0.072	—		
Complete [§]	—			0.515	0.311	0.097
FIM ^{**}	0.332	0.299	0.271	0.301	0.251	0.230
Sports participation ^{††} (hours)	0.297	0.253	0.241	0.261	0.300	0.384

All results are regression coefficients (β) and standard errors (SE) for the final regression model (constant (B) + time dummie + determinant + confounders). The regression coefficients represent the change in outcome associated with an increase in the independent variable PO_{peak} or VO_{2peak} of 1 unit.

Start = start of active rehabilitation; 3 M = 3 months after start; discharge = discharge of inpatient rehabilitation; 1Y and 5Y = respectively 1 and 5 years after discharge of inpatient rehabilitation.

PO_{peak}, peak power output; VO_{2peak}, peak maximal oxygen uptake; NP pain, total score of neuropathic pain; Complete, complete lesion; FIM, functional status; Sport participation, hours per week sports.

A confounder is significant when the constant (B) changes with more than 10% when the confounder is entered in the regression model.

*Significant with $P < 0.05$. NE = not entered.

[†] 0 = women; 1 = men.

[‡] 0 = tetraplegia; 1 = paraplegia.

[§] 0 = incomplete; 1 = complete.

[¶] 0 = high pain; 1 = low pain.

^{**} 0 = low functional status; 1 = high functional status.

^{††} 0 = low sports participation; 1 = high sports participation.

Δ = the time interval.

The change model (Table 5) showed a significant association between change of wheelchair exercise capacity and life satisfaction total. An improvement of 10 Watts in PO_{peak} was associated with an improvement of 0.28 in life satisfaction total score. A progression of 0.1 l/minute VO_{2peak} was associated with a progression

of 0.1 in life satisfaction total scores. Age was a confounder in the relation between the change in PO_{peak} and the change in life satisfaction total and sports participation was a confounder for both the change scores in PO_{peak} and VO_{2peak} and the change score in life satisfaction total.

Table 5 Data on the longitudinal relation between the change in wheelchair exercise capacity (ΔPO_{peak} and ΔVO_{2peak}) and the change in life satisfaction: final random coefficient model

Independent variable	Model with PO _{peak} as determinant			Model with VO _{2peak} as determinant		
	Beta	SE	P	Beta	SE	P
Constant Δ Life Satisfaction	0.462	0.470		0.336	0.209	
ΔPO _{peak} (W)	0.028	0.011	0.011*	NE	NE	
ΔVO _{2peak} (l/min)	NE	NE		0.981	0.497	0.049*
<i>Confounder</i>						
Age [§] (years)	−0.004	0.010	0.689	—	—	—
Sport participation ^{**} (hours)	−0.006	0.271	0.982	−0.076	0.269	0.779

All results are regression coefficients (β) and Standard Errors (SE) for the regression model (constant + time dummy + determinant). Final regression model (constant + determinant + confounders). The regression coefficients represent the change in outcome associated with a change in the independent variable ΔPO_{peak} and ΔVO_{2peak} of 1 unit.

PO_{peak}, peak Power Output; VO_{2peak}, peak maximal oxygen uptake; Sport participation, hours per week sports; ΔPO_{peak} = change in PO_{peak}; ΔVO₂ = change in VO_{2peak}; NE, = not entered.

*Significant with $P < 0.05$.

**0 = low sports participation; 1 = high sports participation; A confounder is significant when the constant (B) changes with more than 10% when the confounder is entered in the regression model.

[§]0 = older than 40 years, 1 = younger than 40 years.

Discussion

Our hypothesis, that patients with SCI with high wheelchair exercise capacity would demonstrate high life satisfaction, is confirmed by this study. Moreover, change in exercise capacity was positively associated with life satisfaction. The changes in both models are nearly identical. Therefore, we conclude that the relationship between exercise capacity and life satisfaction is mainly due to individual (within-subject) variance instead of group (between-subject) variance. This implies that patients who improve their physical fitness might expect improved life satisfaction.

Exercise capacity and quality of life in SCI patients

To the best of our knowledge, no similar studies have been published on the longitudinal relationship between wheelchair exercise capacity and life satisfaction in patients with SCI. Our results provide additional evidence of the positive relationship between exercise participation (specifically sports) and quality of life-related entities, such as life satisfaction,³⁷ mood,⁷ depression,⁹ well-being,^{10,11} mental stress,^{12,13} self-perception of capacities,¹⁴ and overall self-perception.¹⁵ Additionally, a previous meta-analysis reported a positive correlation between participation in leisure-time physical activities and subjective well-being in patients with SCI.¹⁸

Here, we are also able to establish a relationship between changes in wheelchair exercise capacity and life satisfaction. Participation in sport activities was a consistent confounder in this relationship. For comparison, a single study reported the positive effects of a 10-week fitness training program on subjective well-being in patients with SCI.⁸ A small Canadian case-control study on a 9-month SCI training program reported that people who exercised twice per week reported less stress, pain, and depression, and improved physical self-perception, health-related quality of life, and overall subjective well-being compared with the control group.^{10–13} However, a Dutch study reported no association between exercise capacity and health-related quality of life in tetraplegic patients who received handcycling training.¹⁷ Furthermore, no relationship was found between physical activity, fitness, and subjective quality of life in patients with SCI in another cross-sectional study.¹⁶ The designs of these studies and their small group sizes might explain the contradictory results. Due to the assumed direct effects of sports on wheelchair exercise capacity, we focused on the confounding effects of *sports participation* over the broader constructs of leisure-time physical activity, mainly because the latter also includes less intense physical activities like housekeeping and gardening.^{33,38}

There are a few hypotheses on the underlying causes of the association between exercise capacity and life satisfaction. Increasing exercise capacity by training and/or physical daily activity will most likely increase the general health of patients with SCI.^{14–17} In fact, exercise is so beneficial that it should be considered a medicine, as proclaimed by the American College of Sports Medicine.³⁹ Evidence in the general population indicates that exercise should be prescribed for the primary and secondary prevention of pulmonary and cardiovascular diseases, metabolic disorders, cancer, pain, depression, and various muscle, bone, and joint diseases.³⁹ In addition to the physical benefits of exercise, many positive effects on life satisfaction have been reported in both the general population and patients with SCI.^{21,40,41}

The direct benefits of exercise on life satisfaction are the neuro-hormonal results of the endorphins and oxytocin that are produced during and after exercise.⁶ Indirect improvement in life satisfaction might be due to improved exercise capacity, which seems to be positively correlated with improved functional independence, lower levels of depression, higher social status, and improved self-esteem in persons with SCI.^{38,42} Moreover, genetics could influence both life satisfaction and exercise capacity in the general population.⁴¹ Altogether, the findings in the literature support our findings of a positive relationship between wheelchair exercise capacity and life satisfaction.

Confounding variables

All potential confounders could theoretically influence the relationship between life satisfaction and wheelchair exercise capacity, but only some demonstrated a significant change ($\beta \geq 10\%$; see Methods). We found different confounders for VO_{2peak} and PO_{peak} in their relationship with life satisfaction. This could be explained by the fact that VO_{2peak} and PO_{peak} are strongly related but not exchangeable identities. We found different confounders between the two models (standard and change model), which is consistent with previous studies reporting that injury severity significantly affects life satisfaction (standard model) but not the course of life satisfaction (change model).^{26,29}

Clinical relevance, implications, and research recommendations

Improvement in PO_{peak} with 10 W implies an effect size of 0.59 (10 of 17) and improvement of 0.14 (0.2 of 2.2) implies an effect size in life satisfaction, which might not seem clinically relevant. However, life satisfaction is a multidirectional entity that is affected by genetic

and environmental factors,⁴¹ including financial resources and economical and political stability.^{43,44} Furthermore, SCI-related physical factors, such as pain, secondary impairments, and low functional status,^{23,24,28,29} and psychosocial factors, such as personality, appraisal, social support, and self-efficacy,^{23,45,46} are all predictors of life satisfaction. In this context, it is encouraging that a significant relationship between wheelchair exercise capacity and life satisfaction was found. Up to 20% improvement in peak oxygen uptake and peak power can be achieved by patients with SCI who participate in training regimes,^{17,47} and the subsequent improvement in life satisfaction is comparable to positive major life events such as marriage.⁴³ When viewing life satisfaction as an important rehabilitation outcome,²⁵ our results could be considered clinically relevant. In our opinion, there are many convincing arguments that fitness is part of a healthy lifestyle.

This study confirms that most patients with SCI in the Netherlands demonstrate improvements in wheelchair exercise capacity^{26,27} and life satisfaction^{28,29} through 5 years postdischarge (Table 2). Nevertheless, we want to emphasize that both of these characteristics are lower than in the general population,^{24,25} and, in our studies on wheelchair exercise capacity and life satisfaction,^{27,45} different classes of deterioration were identified. In long-term SCI rehabilitation programs, clinicians need to identify the “*persons at risk*” for poor health, including low wheelchair exercise capacity and low life satisfaction. In our opinion, conducting wheelchair exercise tests and measuring life satisfaction during inpatient rehabilitation and follow-up care are warranted. Sufficiently large cohort studies in other countries that include early-onset patients are still needed in order to compare and identify people at risk for poor physical and mental adaptation.

Study limitations

In longitudinal studies that require physically demanding wheelchair exercise tests, loss on follow-up is inevitable; here, only 58% of patients with ≥ 2 wheelchair exercise capacity measurements could be included in our analyses. This figure would have been higher if we included all persons with ≥ 1 wheelchair exercise capacity measurement, but this seemed too speculative even though our analytical strategy would have allowed it.³⁶ Most reasons for not attending exercise tests were health-related, e.g. pain or infection. The life satisfaction scores of the nonparticipants were significantly lower than the study group, which is in agreement with our previous finding; specifically, that life

satisfaction is associated with health conditions such as secondary impairment and pain.^{28,29}

The nonparticipant group was older and included more persons with tetraplegia; both of these entities are associated with low wheelchair exercise capacity^{5,26,27} and dropout of follow-up.⁴⁸ Moreover, lesion level was a confounder in the relationship between wheelchair exercise capacity and life satisfaction. Most likely, the loss of older patients with tetraplegic lesions influenced our results.

This is a longitudinal observational study; therefore, no causal relationships can be drawn between life satisfaction and exercise capacity. Total life satisfaction score is not commonly used worldwide as a measure of life satisfaction in patients with SCI, but it demonstrates similar psychometric properties in comparison with other life satisfaction measures.³⁵

Conclusion

In our SCI cohort, wheelchair exercise capacity and life satisfaction are longitudinally associated up to 5 years after discharge from inpatient rehabilitation. Improvement in exercise capacity is associated with improvement in life satisfaction.

Suppliers

- Jaeger Toennies, Nikkelstr 2, 4823 AB Breda, the Netherlands.
- Treadmill Giant; Bonte BV, Rechterland 25, 8024 AH, Zwolle, the Netherlands.
- Polar Electro Finland Oy, Professorintie 5, FIN-90440 Kempele, Finland.
- SPSS Inc, 233 S Wacker Dr, 11th Fl, Chicago, IL 60606.
- MLwiN version 1.1; Center for Multilevel Modelling, Institute of Education, London, UK

Clinical message

- Wheelchair exercise capacity and life satisfaction recover from start of active rehabilitation up to 5 years after discharge in SCI population.
- Wheelchair exercise capacity and life satisfaction are longitudinally related: persons, who are more fit, are more satisfied in life.
- A positive change in wheelchair exercise capacity leads to a positive change in life satisfaction, this means that persons who are able to improve their physical fitness, might expect an improvement of their life satisfaction.

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