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ORIGINAL ARTICLE

Fatigue in persons with subacute spinal cord injury who are dependent on a manual wheelchair

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Study design: Cross-sectional.
Objectives: To determine the prevalence and severity of fatigue in persons with subacute spinal cord injury (SCI), assess whether demographic and lesion characteristics are related to fatigue and determine the relationship with physical fitness and physical behavior.
Setting: Measurements were performed 2 months before discharge from inpatient rehabilitation.
Methods: Thirty-six persons with subacute SCI, dependent on a manual wheelchair, mean age 43 ± 15 and 83% men, completed the Fatigue Severity Scale (FSS). FSS scores >4 indicated fatigue. We recorded age and lesion characteristics, measured body mass index, measured peak power output and peak oxygen uptake during a maximal handcycling test and determined physical behavior using an accelerometer-based activity monitor. *T*-tests were used to test for differences in fatigue between subgroups based on age and lesion characteristics, and regression analyses to assess the relationship with physical fitness and physical behavior.
Results: Mean FSS was 3.3 ± 1.3. Fatigue, including severe fatigue, was prevalent in 31% (95% confidence interval: 16–46) of participants compared with 18% in the general population. Furthermore, mean fatigue was significantly higher in persons with incomplete compared with complete lesions ($t=2.22$, $P=0.03$). Mean scores between other subgroups did not differ significantly. Of the physical fitness and physical behavior measures, only peak oxygen uptake tended to be related to more fatigue ($B=-1.47$, $P=0.05$).
Conclusion: Fatigue was prevalent and is of concern in persons with subacute SCI. Those with incomplete lesions seem to be at higher risk. Because fatigue is known to persist among persons with SCI, interventions to reduce fatigue seem necessary.
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INTRODUCTION

Spinal cord injury (SCI) is a chronic condition that causes paralysis and leads to multiple associated symptoms, including fatigue. Fatigue has been defined as an overwhelming sense of tiredness, lack of energy and often a feeling of total exhaustion.[1] Fatigue is known to negatively impact quality of life.[2] In persons with SCI in the chronic phase, at least 1-year post injury, fatigue has been reported in more than half of the persons and has been found to interfere with daily functioning.[3–5] To our knowledge, the prevalence and severity of fatigue in persons with subacute SCI is unknown.

The first step in preventing fatigue is to identify persons at risk. If demographic and lesion characteristics related to fatigue are known, subgroups at higher risk can be identified. Furthermore, fatigue has been suggested to be related to low daily physical activity and physical fitness levels within a cycle of deconditioning.[6] Because both daily physical activity and physical fitness levels are known to be low in persons with SCI,[7,8] these factors may influence fatigue development. Besides physical activity, amount of sedentary day time is another independent aspect of physical behavior[9] that might impact fatigue. Assessing the impact of physical behavior and physical fitness on fatigue may help optimize interventions.

Fatigue is thought to be a multifactorial problem. In persons with SCI in the chronic phase, fatigue has been shown to relate to age[10] and lesion characteristics.[4] With regard to physical factors, being overweight has been found to negatively impact fatigue,[11] and physical activity that requires a lot of physical effort[12] is related to less fatigue in persons with SCI in the chronic phase.

Knowledge of fatigue in (subgroups of) persons with subacute SCI may help prevent chronic-phase fatigue. It is unknown whether fatigue onset immediately follows SCI or develops over time. Furthermore, it is unknown which physical factors are associated with fatigue development in persons with subacute SCI. Therefore, the goal of this study was to determine the prevalence and severity of fatigue in persons with subacute SCI who are wheelchair dependent and assess whether demographic and lesion characteristics are related to fatigue. Demographic and lesion characteristics studied include the following: age, sex, lesion level and lesion completeness. Second, we determined the relationship of physical fitness and physical behavior to fatigue.

MATERIALS AND METHODS

Design

This study is part of Act-Active, a longitudinal multicenter randomized controlled trial that includes a behaviorally focused intervention on physical

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behavior in persons with subacute SCI, registered at the Dutch trial register, NTR2424. Persons were recruited from four Dutch rehabilitation centers, and target sample size was 60 participants. The current study, in which we analyzed baseline data from Act-Active, has a cross-sectional design.

Participants

Inclusion criteria were the following: (1) SCI, both traumatic or non-traumatic, (2) participation in initial inpatient rehabilitation, (3) dependence on a manual wheelchair, (4) age 18–65 years and (5) sufficient comprehension of the Dutch language. Exclusion criteria were psychiatric conditions or progressive diseases that could interfere with participation as determined by a rehabilitation physician. The study was approved by the Medical Ethics Committee of the Erasmus Medical Center Rotterdam, and all participants provided written informed consent. A rehabilitation physician screened participants for contraindications to maximal exercise including recent cardiovascular events and a diastolic blood pressure >90 mm Hg or systolic blood pressure >180 mm Hg at rest. Furthermore, all participants completed the Physical Activity Readiness Questionnaire.[13] Data were collected 2 months before discharge from inpatient rehabilitation, before the start of the Act-Active interventions. This measurement point was determined based on the discharge date set by the rehabilitation physician. At this standardized time in rehabilitation, all participants, regardless of the lesion level and completeness, were expected to be engaged in active inpatient rehabilitation.

Outcome measures

Fatigue was measured using the Fatigue Severity Scale (FSS), a validated questionnaire assessing the perceived impact of fatigue on an individual's daily functioning.[14] The range of answer possibilities is 1–7, and the total FSS score is the mean of nine questions. The mean Dutch general population score is 2.9 ± 1.1.[15] 'Severe fatigue' was defined as a score on the FSS of >2 s.d. above the mean score in the general population ($\text{FSS}\geqslant5.1$).[15] 'Fatigue' was defined as a score on the FSS of >1 s.d. above the mean score in healthy individuals ($\text{FSS}>4.0$).[15] The prevalence of fatigue in our sample was compared with the prevalence of fatigue in the general population (fatigue in 18% and severe fatigue in 4%).[16]

Participant sex and age were recorded. We defined persons 50 years or older as an older person and grouped participants into two age groups, <50 years and $\geqslant50$ years. A rehabilitation physician assessed the lesion level and motor completeness. Paraplegia was defined as a lesion below Thoracic 1 (T1) and tetraplegia as a lesion at or above the T1 segment. Motor completeness included the AIS (American Spinal Injury Association Impairment Scale) categories A and B and motor incompleteness included AIS C and D.

Body mass index (BMI in kg m^{-2}) was calculated from height and body mass. Physical capacity was determined by performing a maximal handcycle test on a Tacx Flow ergotrainer (Tacx, Wassenaar, The Netherlands and Double Performance, Gouda, The Netherlands). During the test, the participants were seated in an add-on hand cycle provided by the rehabilitation center. The test started after a 3-min warm-up period with minimal resistance. Resistance was increased every minute by 2–10 W, depending on lesion characteristics. During the test, persons were instructed to keep cycling at a rate of 60 rpm. The test ended when the participant indicated to be too exhausted to continue despite verbal encouragements of the research assistant or when failed to keep cycling at the rate of 60 rpm. Oxygen uptake (VO_2) was measured with an Oxycon Delta (Jaeger, Hoechberg, Germany). $\text{VO}_{2\text{peak},}$ in milliliters per minute (ml min^{-1}), was determined and defined as the highest mean oxygen uptake during 30 s. Furthermore, power was measured continuously with an ergotrainer. When using correction equations, the Tacx Flow ergotrainer was found to be a reliable and a valid instrument for power estimation. Peak power output (PO_{peak}), in Watts, was defined as the highest power output sustained for a minimum of 30 s.

Physical behavior was measured objectively using the VitaMove activity monitor (2M Engineering, Veldhoven, The Netherlands) (Figure 1), an ambulatory monitoring system with body-fixed accelerometers (Freescale MMA7260Q, Denver, CO, USA).[17,18] The system consists of three recorders that are wirelessly connected and synchronized every 10 s. One recorder was attached to the sternum and another to each wrist using specially developed belts. The activity monitor was worn continuously for 96 h on four week days, except during swimming, bathing and sleeping. Because of logistic and technical reasons, the measurement duration goal of 96 h was not always met; the minimum required duration was 24 h for inclusion in analysis. To avoid measurement bias, participants were instructed to continue their ordinary daily life, including therapies. The principles of the activity monitor were explained only after participants completed the randomized controlled trial. Measurements were uploaded to a computer for kinematic analysis using VitaScore Software (VitaScore BV, Gemert, The Netherlands). A detailed description of this configuration and analysis has been described elsewhere.[18]

Figure 1 VitaMove activity monitor.

Every second of the measurement was assigned to one of the four categories: sitting, lying, wheelchair propulsion and hand cycling. The following outcome measures were determined as a mean of available measurement days:

a. Duration of wheeled physical activity, including wheelchair propulsion and hand cycling, in hours per 24-h period.

b. Sedentary day time, including sitting and lying, in hours per 24-h period.

c. Motility, mean variability of the trunk and arm signals independent of the assigned category, a measure of intensity and duration of all physical behavior, in g × 100 (gravitational forces), per 24-h period.

Data analysis

Descriptive statistics were used to summarize participant characteristics and describe the prevalence and severity of fatigue. Parametric tests were used because the Shapiro–Wilk test showed that fatigue data were normally distributed ($W(36)=0.95$, $P=0.09$). Independent *t*-tests were used to test for mean differences between subgroups. Secondary, separate regression models with fatigue as a dependent variable were made for the physical fitness (BMI, $\text{VO}_{2\text{peak}}$ and PO_{peaK}) and physical behavior (physical activity duration, sedentary day time and motility) measures. Assumptions for normality and collinearity for regression analysis were met. In the regression models, possible confounding effects of demographic and lesion characteristics were assessed. Demographic and lesion characteristics were added one by one to the regression models of the physical fitness and physical behavior measures. At first, the characteristic causing the largest change in *B* (unstandardized regression coefficient) of the independent variable, with a minimum change of 10%, was added to the model as a confounding variable. This procedure was repeated for the remaining characteristics and ended when none of the characteristics caused a change in *B* of $>10\%$. Because of the limited sample size, a maximum of two confounders were added to each regression model. We reported *B*, standard errors, 95% confidence intervals, ß and *P*-values for the regression analyses. The statistical significance level was set at $P<0.05$ (SPSS Inc, Chicago, IL, USA).

We certify that all applicable institutional and governmental regulations concerning the ethical use of human volunteers were followed during the course of this research

RESULTS

Between January 2011 and August 2013, 45 persons with SCI agreed to participate in the randomized controlled trial Act-Active. FSS data were not available for nine persons; therefore, the present study included data for 36 participants. In these 36 participants, there were data missing for physical fitness and physical behavior. BMI was not available in two persons. Furthermore, eight participants were unable to perform maximal handcycle testing due to contraindications to maximal exercise. VO_2 data were not available for an additional three participants, two because of technical problems and one because of a bacterial infection. Physical behavior data were missing for three participants because of logistical reasons.

Table 1 shows participant characteristics. Mean FSS was 3.1 (s.d. 0.5) for women and 3.3 (s.d. 1.4) for men. Our sample included only five women, and all five had complete paraplegia. None of the women had scores indicating fatigue, and 36% of men had scores indicating fatigue or severe fatigue. Because the group of women was small and uniform in lesion characteristics, sex was not statistically assessed in relation to fatigue.

Table 2 shows the prevalence and severity of fatigue for the entire group and for subgroups based on lesion characteristics and age. The mean score for our sample was 3.3 (s.d. 1.3). Persons with motor incomplete lesions had significantly higher FSS scores compared with those with complete lesions ($t=2.22$, $P=0.03$).

Table 3 shows the regression models assessing the relationship between fatigue and physical fitness and physical behavior. The mean BMI was 25.0 (s.d. 5.0), mean PO_{peak} was 49.1 W (s.d. 31.4) and mean VO_{2peak} was 1304.0 ml min^{-1} (s.d. 484.6). The relationship between fatigue and VO_{2peak} bordered on statistical significance ($B=-1.47$, $P=0.051$). Persons with lower VO_{2peak} tended to be more fatigued. BMI and PO_{peak} were not significantly related to fatigue. On average, participants were physically active for 1.2 h (s.d. 0.5) per 24-h period, sedentary for 10.5 h (s.d. 1.2) during waking hours and mean motility was 16.5 g (s.d. 4.2). No significant relationships were found between any physical behavior measures and fatigue.

Table 1 Participant characteristics ($n=36$)

Age, years, mean (s.d.)	43 (15)
Sex, %	
Men	86
Women	14
Lesion level, %	
Paraplegia	67
Tetraplegia	33
AIS score, %	
A	47
B	17
C	17
D	19
Time since injury in months mean (s.d.)	4.7 (2.4)
Time in rehabilitation in months, mean (s.d.)	3.4 (2.0)
Cause of lesion, %	
Traumatic	74
Nontraumatic	26

Abbreviation: AIS, American Spinal Injury Association Impairment Scale.

DISCUSSION

Fatigue was prevalent and is of concern in persons with subacute SCI. Persons with incomplete lesions seem to be at higher risk. Rehabilitation professionals should recognize fatigue complaints and the possible impacts of fatigue. Because fatigue is known to persist among persons with SCI,[3–5] intervention to reduce fatigue is necessary.

Our sample seems representative for the Dutch population, as demographic and lesion characteristics are comparable to those reported in a previous large Dutch cohort study.[19] Previous studies in persons with SCI in the chronic phase included relatively larger proportions of participants with incomplete lesions or tetraplegia.[3–5] This might partly explain that the prevalence of fatigue in our participants with subacute SCI was lower compared with the 52–57% prevalence previously reported for persons with SCI in the chronic phase.[3–5] Prospective studies assessing the course of fatigue are needed.

The finding that persons with incomplete lesions are more fatigued compared with persons with complete lesions was also described by Fawkes-Kirby *et al.*[4] in a study of persons with SCI in the chronic phase. Those authors proposed that person with incomplete lesions attempt to complete more activities and rely less on assistive devices or care attendants; therefore, their total daily energy expenditure and the physiological energy cost of specific activities would be larger.[6] In this study, we did not find any relationship between fatigue and total duration of physical activity or activity intensity (motility). Physical activity duration was similar between subgroups based on SCI completeness (1.2 h (s.d. 0.5) for both groups), and motility was also comparable (16.9 g (s.d. 5.1) for those with incomplete lesions and 16.2 g (s.d. 3.7) for those with complete lesions). However, we only applied the activity monitor to measure postures, wheeled activities and motility of the trunk and arms. Although all study participants were wheelchair dependent, persons with incomplete lesions may use their legs to reposition in the chair or make transfers. We suggest that these types of activities may cause more fatigue in persons with incomplete lesions.

Persons 50 years or older had a fatigue prevalence of 41% versus 28% for persons younger than 50. However, we found a relatively high prevalence (13%, $n=3$) of severe fatigue among persons younger than 50. Of these three severely fatigued participants, two had incomplete tetraplegia and all were 40 years or older. These characteristics may partly explain this unexpected high prevalence of severe fatigue in the subgroup younger than 50. In a previous study, older age was associated with more fatigue.[10] Further studies with larger samples are necessary.

Our finding that aerobic capacity tended to relate to fatigue indicates that there may be a physical origin of fatigue in persons with subacute SCI. This finding underscores the importance of aerobic capacity training in the early rehabilitation phase.[20] Our finding is consistent with that of a previous study that showed that less exercise was related to more fatigue [5] and heavy intensity activity was related to lower fatigue in persons with chronic SCI.[12] However, we found no relationship between fatigue and physical behavior in our study. Therefore, we could not confirm the fatigue, physical fitness and physical behavior cycle hypothesis proposed by Durstine *et al.*[6] However, our physical behavior measurement was limited to outcomes on postures, wheeled physical activity and mean motility of trunk and arms. We did not specifically assess the amount and type of therapy of the participants. Moreover, for this group, daily self-care is already time-consuming and straining every day activity.[21] Unfortunately, physical strain was not assessed in the present study. Future research should assess duration and type of therapy in relation to

Table 2 Prevalence of fatigue

	All	*Age*		*Lesion level*		*Completeness*	
		< 50 yrs	*⩾ 50 yrs*	*Paraplegia*	*Tetraplegia*	*Incomplete*	*complete*
	n = *36*	n = *24*	n = *12*	n = *24*	n = *12*	n = *13*	n = *23*
Mean (s.d.)	3.3 (1.3)	3.2 (1.4)	3.6 (1.2)	3.0 (1.1)	3.9 (1.5)	3.9 (1.4)	3.0 (1.1)
t-Test results		$t=-0.85$, $P=0.40$		$t=-1.83$, $P=0.08$		$t=2.22$, $P=0.03$[a]	
Fatigued[b] (%)	31[c]	25	41	21	50	46	21
(95% CI)	(16–46)						
Severely fatigued[d] (%)	11[c]	13	8	8	17	15	9
(95% CI)	(1–21)						

Abbreviation: CI, confidence interval.
[a] Indicates significant difference between subgroups.
[b] Fatigue Severity Scale (FSS) >4.
[c] General population: fatigue in 18% and severe fatigue in 4%.[16]
[d] FSS ⩾ 5.1.

Table 3 Regression models with fatigue as the dependent variable and physical fitness and physical behavior measures as the independent variables

Independent variable[a]	*FSS*				
	B	*s.e.*	*95% CI*	β	P
BMI, *n*=34	−0.004	0.05	−0.10 to 0.09	−0.02	0.93
Age	0.02	0.02	−0.02 to 0.05	0.19	0.28
Completeness	−0.96	0.46	−1.90 to −0.03	−0.35	0.04
VO_{2peak}, *n*=25	−1.47	0.71	−2.94 to 0.00	−0.48	0.05
Lesion level	−0.26	0.91	−2.15 to 1.63	−0.09	0.78
Completeness	−1.23	0.73	−2.75 to 0.29	−0.41	0.11
PO_{peak}, *n*=28	−0.01	0.01	−0.04 to 0.01	−0.27	0.27
Lesion level	0.54	0.68	−0.87 to 1.95	0.19	0.44
Physical activity, *n*= 33	0.18	0.51	−0.87 to 1.23	0.07	0.73
Age	0.02	0.02	−0.02 to 0.06	0.22	0.25
Lesion level	0.82	0.48	−0.17 to 1.81	0.31	0.10
Sedentary day time, *n*=33	−0.17	0.20	−0.56 to 0.23	−0.16	0.41
Age	0.02	0.02	−0.02 to 0.05	0.17	0.36
Completeness	−0.72	0.48	−1.70 to 0.25	−0.27	0.14
Motility, *n*=33	−0.03	0.06	−0.17 to 0.10	−0.11	0.61
Age	0.01	0.02	−0.03 to 0.04	0.06	0.77
Completeness	−0.88	0.47	−1.85 to 0.09	−0.33	0.07

Abbreviations: *B*, unstandardized regression coefficient; *β*, standardized regression coefficient; CI, confidence interval; FSS, Fatigue Severity Scale; PO_{peak}, peak power output; VO_{2peak}, peak oxygen uptake.
[a] Each determinant was analyzed in a separate regression model.

fatigue and should study the relation between physical strain and fatigue in persons with subacute SCI. Furthermore, previous studies show that fatigue is a multifactorial problem and that other factors such as pain, depression, sleep-related problems such as sleep apnea and medication[3,5,22] contribute to fatigue development. Further research should address the effects of these parameters on fatigue development in persons with subacute SCI.

Because fatigue is known to persist in persons with SCI in the chronic phase, intervention seems necessary. To our knowledge, fatigue interventions in persons with SCI have not been studied previously. In other person groups, a self-management program[23] and an exercise training program have been shown to reduce fatigue.[24] Further research on interventions in persons with SCI is necessary.

Study limitations

Our study is limited by its cross-sectional design, and we cannot, therefore, infer causality from the results. Sample size calculation was performed based on the randomized controlled trial, and the sample was limited to 36 participants. We could not assess sex as a determinant because our sample included only five women. Furthermore, because of multiple testing and the number of variables in the regression models, one should be careful to draw strong conclusions from individual results. Also, physical behavior was limited to weekday measurements. Longitudinal studies are needed to evaluate the course of fatigue and its determinants in persons with subacute SCI. Furthermore, our study was limited to persons who are dependent on a manual wheelchair and were younger than

65 years. Therefore, future research should assess fatigue in ambulatory persons, persons dependent on power wheelchairs and persons older than 65 years.

DATA ARCHIVING

There were no data to deposit.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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