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ORIGINAL ARTICLE

A more active lifestyle in persons with a recent spinal cord injury benefits physical fitness and health

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Study design: A prospective cohort study.
Objectives: To study the longitudinal relationship between objectively measured everyday physical activity level, and physical fitness and lipid profile in persons with a recent spinal cord injury (SCI).
Setting: A rehabilitation centre in the Netherlands and the participant's home environment.
Methods: Data of 30 persons with a recent SCI were collected at the start of active rehabilitation, 3 months later, at discharge from inpatient rehabilitation, and 1 year after discharge. Physical activity level (duration of dynamic activities as % of 24 h) was measured with an accelerometry-based activity monitor. Regarding physical fitness, peak oxygen uptake (VO_2peak) and peak power output (POpeak) were determined with a maximal wheelchair exercise test, and upper extremity muscle strength was measured with a handheld dynamometer. Fasting blood samples were taken to determine the lipid profile.
Results: An increase in physical activity level was significantly related to an increase in VO_2peak and POpeak, and an increase in physical activity level favourably affected the lipid profile. A nonsignificant relation was found with muscle strength.
Conclusion: Everyday physical activity seems to have an important role in the fitness and health of persons with a recent SCI. An increase in physical activity level was associated with an increase in physical fitness and with a lower risk of cardiovascular disease.
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Keywords: spinal cord injury; physical activity; accelerometry; physical fitness; cardiovascular disease

INTRODUCTION

Most persons with a spinal cord injury (SCI) have an inactive lifestyle.[1] Van den Berg-Emons *et al.*[2] studied the course of everyday physical activity level of persons with SCI. During inpatient rehabilitation, the levels of physical activity improved. However, shortly after discharge from the rehabilitation centre the levels declined sharply. One year after discharge, activity levels had recovered somewhat but were still much lower than those of able-bodied persons and were even lower than those of persons with other chronic diseases.[3]

Besides these low everyday activity levels, it is known that the physical fitness of persons with a SCI is generally low and that they have an enlarged risk of cardiovascular disease.[4] In the able-bodied population, it is well-known that physical activity has a positive effect on health. This relation has also been studied in persons with a SCI.[5–11] However, these studies all used questionnaires to determine physical activity level. Although studies have shown that when using questionnaires there is a risk of overestimation and that self-reported activity level is only weakly related to objectively measured activity level.[12] Another shortcoming of previous studies is that most studies had a cross-sectional design.

The purpose of this study was to assess the longitudinal relationship between objectively measured everyday physical activity, and physical fitness and lipid profile in persons with a recent SCI. We used an accelerometry-based activity monitor to determine everyday physical activity. With this monitor, we could determine the duration someone was performing dynamic activities (mainly wheelchair driving, hand-cycling and walking). This included all everyday physical activities with varying intensities, not only sports. We hypothesized that persons who were more physically active were physically fitter and had a more favourable lipid profile.

MATERIALS AND METHODS

Design

This prospective cohort study was part of the national research program 'Physical Strain, Work Capacity and Mechanisms of Restoration of Mobility in the Rehabilitation of Individuals with Spinal Cord Injuries'. All data were collected at four test occasions: at the start of active inpatient rehabilitation (t1), 3 months later (t2), at discharge from inpatient rehabilitation (t3) and 1 year after discharge (t4).

Inclusion criteria were: initial inpatient rehabilitation, 18 to 65 years old, (partly) dependent on a manual wheelchair during inpatient rehabilitation, and sufficient comprehension of Dutch. Exclusion criteria were: cardiovascular contraindications for exercise, and progressive disease or psychiatric condition that could interfere with participation. The Medical Ethics Committee of the Rehabilitation Center, Hoensbroek, The Netherlands approved the protocol of the national research program and the Medical Ethics Committee of Erasmus Medical Center, The Netherlands the protocol of this study.

Participants

Participants were recruited during inpatient rehabilitation at Rijndam Rehabilitation Center in Rotterdam from 2001 until 2005. All eligible persons were asked to participate. A total of 42 persons with a SCI agreed to participate. Data on two participants were excluded because these persons became completely ambulatory during their inpatient period. Data on an additional 10 participants were excluded because only 1 of the minimum of 2 required physical activity

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measurements was available. Average time of inpatient rehabilitation of the remaining 30 participants was 7 months (range: 2–15 months).

Physical activity level

Everyday physical activity level was objectively measured for 48 h during 2 consecutive weekdays using an accelerometry-based activity monitor (Vitaport; Temec Instruments, Kerkrade, The Netherlands and Analog devices Nederland, Breda, The Netherlands).[2] This activity monitor has shown to be reliable,[13] and valid for persons with SCI.[14] Per participant, one accelerometer was attached to each thigh and wrist, and two accelerometers to the sternum. All accelerometers were connected to a data recorder, which participants wore in a padded bag around the waist. Data were collected on a memory card and downloaded on a computer for analysis with Vitagraph software (Temec Instruments). To avoid measurement bias, principles of the activity monitor were not explained to the participants until all measurements had been completed. Participants were instructed to continue their ordinary daily activities (including therapy and sports), but were not allowed to swim or take a bath or shower during the 2 test days. Data from the activity monitor were analyzed per day, and since there were no significant differences in physical activity between the 2 days, averaged over 2 days. We determined the duration per day a person was performing dynamic activities, including manual wheelchair driving, handcycling, walking and general non-cyclic movement. All activities on varying intensities were included. The total duration of dynamic activities was expressed as a percentage of 24 h.

On the 4 test occasions for the 30 participants, a total of 89 measurements of physical activity level were performed. The baseline data on one participant could not be measured because the person was wearing a corset during that particular measurement period. The t2-measurement was not performed on eight participants because the two test occasions (t2 and t3) were too close to one another. The t3-measurement of four participants was missing for personal reasons or technical problems with the activity monitor. Three other participants dropped out at t3: two died and one had personal reasons. Data at t4 were missing for further 12 participants mainly because of personal reasons, and in some cases because of technical problems.

Physical fitness

Aerobic capacity. The peak oxygen uptake (VO_2peak in $l\,min^{-1}$) measured with an Oxycon Delta (Jaeger, Germany) and the peak power output (POpeak in W) were determined during a graded maximal wheelchair exercise test on a treadmill (Lode BV, Groningen, The Netherlands). A detailed description of the procedure was given previously.[15]

Upper extremity muscle strength. Isometric muscle strength was measured with a handheld dynamometer (Biometrics Europe BV, Almere, The Netherlands) using the 'break' testing procedure.[16] The strength (in kN) of five muscle groups (elbow flexors-extensors, shoulder flexors, external rotators and abductors) was assessed on both sides. A sum muscle strength score was calculated by totalling the values of the muscle groups of both sides.

Risk of cardiovascular disease

Lipid profile was measured to get an indication of the risk of cardiovascular disease. Therefore, fasting blood samples were taken. Total cholesterol (TC in $mmol\,l^{-1}$) and triglycerides (TG in $mmol\,l^{-1}$) were determined using standardized enzymatic procedures. For determining the high-density lipoprotein (HDL in $mmol\,l^{-1}$), the very low-density lipoprotein and low-density lipoprotein (LDL) were selectively precipitated. The Friedewald equation was used to compute the LDL concentration (in $mmol\,l^{-1}$). Ratios for TC/HDL and LDL/HDL were calculated.

Possible confounding variables

Age (in years), gender and lesion characteristics were recorded at t1. Tetraplegia was defined as a lesion at or above the Th1 segment, and paraplegia as a lesion below Th1. A complete lesion was defined as motor complete, ASIA grade A or B, an incomplete lesion as ASIA grade C or D. In addition, height was determined (in cm) at t1 and body mass (in kg) was measured on all four test occasions. These measures were used to calculate body mass index (BMI in $kg\,m^{-2}$).

Statistics

For the statistical analysis, physical activity data of a minimum of two test occasions were required. Multilevel regression analysis was used to determine the longitudinal relationship between physical activity level and the different physical fitness and lipid profile parameters (MLwiN version 2.02, Centre for multilevel modeling, Bristol).[17] The dependent variables were the physical fitness (VO_2peak, POpeak, muscle strength) and lipid profile parameters (TC, HDL, LDL, TG, TC/HDL, LDL/HDL). First, nine models were made for the course of these different physical fitness and lipid profile parameters. Time was included as three dummy variables, with t3 as the reference test occasion: t1t3, t2t3 and t4t3. Next, models for the individual relationship with physical activity level were made by adding physical activity level to the nine models. Age, gender, lesion level, completeness and BMI were added separately to the models, to study their possible confounding effects on the relationships. If after adding one of these factors, the β of physical activity level changed by $>10\%$, this factor was marked as a confounder and was added to the final regression models. A *t*-test was performed to test for differences in activity level at t1 between the persons who dropped out ($n=15$) and who had not dropped out at t4 ($n=14$). Significance was set at $P\leqslant 0.05$.

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

Participants

At t1, the mean age of the participants was 42 ± 15 years, 72% were men, 53% had a tetraplegia and 72% a motor complete SCI. The mean BMI at the four test occasions varied between 24.1 ± 4.7 and $24.6\pm4.2\,kg\,m^{-2}$. The *t*-test, used to test for differences in activity level at t1 between the persons who dropped out (mean=3.55%, s.d.=2.29) and who had not dropped out at t4 (mean=2.84%, s.d.=1.92), showed no significant difference ($t=-0.89$, $P=0.38$). The descriptive statistics are presented in Table 1.

Relations

Table 2 shows the relations between physical activity level, and the physical fitness and lipid profile parameters. After correction for confounders, physical activity level was significantly correlated to VO_2peak and POpeak ($P<0.01$). An increase in physical activity level was associated with an increase in aerobic capacity. Corrected for confounders, we found a nonsignificant correlation between activity level and muscle strength ($P=0.09$). With regard to lipid profile, an increase in activity level was correlated to a decrease in concentration of TG ($P<0.01$) and to a decrease in TC/HDL ratio ($P<0.05$).

The coefficients from the models presented in Table 2 can be used to get an indication of the strength of the relations. In this example, we used the actual average increase in physical activity level from t1 to t3. At t1 activity level was 3.21%. This level increased from 1.79 to 5.00% at t3. This increase in 1.79% corresponds with $26\,min\,day^{-1}$. For the relation between activity level and VO_2peak, $\beta=0.059$. This means that corrected for confounders and time, an increase in physical activity level of $26\,min\,day^{-1}$ was associated with an increase in $0.11\,l\,min^{-1}$ ($\beta=0.059*1.79\%$) in VO_2peak. The same increase of $26\,min\,day^{-1}$ was, corrected for confounders and time, for power associated with an increase in 4.06 W ($\beta=2.27*1.79\%$), for TG with a decrease in $0.14\,mmol\,l^{-1}$ ($\beta=-0.076*1.79\%$) and for TC/HDL ratio with a decrease in 0.23 ($\beta=-0.127*1.79\%$).

DISCUSSION

In this longitudinal study of persons with a recent SCI, an increase in objectively measured everyday physical activity level related to a higher physical fitness and to a more favourable lipid profile in persons with a recent SCI. More specifically, an increase in everyday physical activity level was significantly correlated with an increase in

Table 1 Group sizes, means and s.d. of physical activity level and the physical fitness and lipid profile parameters at the four test occasions

	t1: Start		*t2: 3 months later*		*t3: Discharge*		*t4: Year after discharge*	
	n	*Mean (s.d.)*	n	*Mean (s.d.)*	n	*Mean (s.d.)*	n	*Mean (s.d.)*
Activity level (%)	29	3.21 (2.11)	22	4.98 (2.27)	23	5.00 (2.33)	15	3.51 (3.40)
VO_2peak ($l\,min^{-1}$)	20	1.01 (0.37)	19	1.02 (0.47)	25	1.15 (0.45)	15	1.17 (0.47)
POpeak (W)	20	29.17 (16.93)	19	34.40 (22.12)	25	35.25 (21.22)	15	39.34 (21.91)
Muscle strength (kN)	19	1.65 (0.54)	19	1.90 (0.57)	22	2.03 (0.54)	11	1.96 (0.61)
TC ($mmol\,l^{-1}$)	28	4.83 (1.08)	26	4.71 (0.96)	29	4.70 (1.03)	17	5.01 (0.98)
HDL ($mmol\,l^{-1}$)	28	0.99 (0.30)	26	1.15 (0.31)	29	1.20 (0.38)	18	1.17 (0.41)
LDL ($mmol\,l^{-1}$)	28	3.01 (1.12)	26	3.03 (0.95)	29	2.99 (1.01)	18	3.46 (0.96)
TG ($mmol\,l^{-1}$)	28	1.57 (0.57)	26	1.50 (0.72)	29	1.36 (0.62)	17	1.61 (0.98)
TC/HDL	28	5.17 (1.45)	26	4.37 (1.31)	29	4.24 (1.46)	17	4.77 (1.61)
LDL/HDL	28	3.25 (1.36)	26	2.86 (1.20)	29	2.72 (1.19)	18	3.32 (1.53)

Abbreviations: HDL, high-density lipoprotein; LDL, low-density lipoprotein; POpeak, peak power output; TC, total cholesterol; TG, triglycerides; VO_2peak, peak oxygen uptake.
Activity level: duration of dynamic activities, as a percentage of 24 h. An activity level of 3.21% corresponds with performing dynamic activities for 46 min day^{-1}.
Physical fitness: VO_2peak in $l\,min^{-1}$; POpeak in W; muscle strength of the upper extremities in kN.
Lipid profile: in $mmol\,l^{-1}$; TC, HDL, LDL, TG and the ratios TC/HDL and LDL/HDL.

Table 2 Multivariate regression models for the relation between physical activity level, and the physical fitness and lipid profile parameters

	Activity level			*Constant*		*t3t1*		*t3t2*		*t3t4*		*Confounders*		
	β	*s.e.*	P	β	*s.e.*	β	*s.e.*	β	*s.e.*	β	*s.e.*	*Confounder*	β	*s.e.*
VO_2peak ($l\,min^{-1}$)	0.059	0.019	0.002	0.842	0.311	−0.141	0.092	−0.171	0.098	0.059	0.113	Gender	−0.415	0.088
												Lesion level	0.072	0.366
												Completeness	−0.703	0.088
												BMI	0.017	0.009
POpeak (W)	2.27	0.758	0.003	43.69	6.42	−8.05	3.97	−3.13	4.20	2.28	4.78	Gender	−21.13	3.34
												Lesion level	18.01	3.04
Muscle strength (kN)	0.277	0.165	0.093	19.78	3.47	−2.50	0.968	−1.01	0.981	0.163	1.28	Age	−0.035	0.027
												Gender	−8.93	0.934
												Lesion level	3.18	0.817
												Completeness	3.46	0.956
												BMI	0.296	0.093
TC	−0.060	0.045	0.184	5.30	0.36	−0.147	0.282	−0.178	0.291	−0.235	0.347	Lesion level	0.072	0.219
												Completeness	−0.219	0.243
HDL	−0.017	0.016	0.289	1.15	0.109	−0.208	0.103	−0.035	0.106	−0.019	0.124	Lesion level	0.015	0.079
LDL	−0.054	0.045	0.230	3.43	0.310	−0.237	0.292	−0.172	0.302	0.026	0.351	Lesion level	−0.021	0.225
TG	−0.076	0.025	0.002	0.212	0.388	0.091	0.016	0.033	0.165	0.287	0.197	Lesion level	0.344	0.124
												BMI	0.073	0.014
TC/HDL	−0.127	0.061	0.038	5.01	0.421	0.575	0.404	−0.242	0.413	0.040	0.495			
LDL/HDL	−0.098	0.057	0.087	3.34	0.390	0.227	0.375	−0.166	0.384	0.170	0.450			

Abbreviations: BMI, body mass index; HDL, high-density lipoprotein; LDL, low-density lipoprotein; POpeak, peak power output; TC, total cholesterol; TG, triglycerides; VO_2peak, peak oxygen uptake.
β Indicates the regression coefficient.
t3t1, t3t2, t3t4 indicate time as three dummy variables, with t3 as reference test occasion
Definition of confounders: gender, male = 0 and female = 1; lesion level, tetraplegia = 0 and paraplegia = 1; completeness, incomplete = 0, complete = 1.

aerobic capacity (VO_2peak and POpeak). Furthermore, an increase in physical activity level favourably affected two of the six lipid profile parameters (TG and TC/HDL), indicating reduced risk of cardiovascular disease.

Our results confirm the findings of three previous studies,[5–6,10] which correlated activity level to aerobic capacity in persons with SCI. These three studies, in which questionnaires were used to ascertain physical activity level, found low-to-moderate correlations. In our study, an increase in activity level of 26 min day^{-1} was associated with an increase in VO_2peak of 0.11 $l\,min^{-1}$. This increase seems clinically relevant, because the average VO_2peak at discharge was only 1.15 $l\,min^{-1}$ (10% increase). Not all previous studies that have objectively measured physical activity in persons with other physical disabilities have found this correlation with aerobic capacity. No relation was found in a study of ambulatory persons with cerebral palsy,[18] and in another study, on persons with myelomeningocele, a correlation was only found in the non-ambulatory group.[19] It seems that activity level is correlated with aerobic capacity only in persons with a very low aerobic capacity, that is, wheelchair users who are subject to a sedentary lifestyle.

We found a nonsignificant relation between activity level and muscle strength. To our knowledge, only one previous study has assessed this relation in persons with a recent SCI.[10] In that study, in which a questionnaire was used to ascertain activity level, a weak correlation was found. More research is necessary to elucidate this relationship.

The correlation between activity level and lipid profile suggests that persons with a SCI who are more physically active have less risk of cardiovascular disease. Of the 30 participants, 5 had elevated TG levels ($>2.00\,\mathrm{mmol\,l^{-1}}$) at the start of the study, compared with 2 at discharge from the rehabilitation centre. At the start of the study, 15 persons had elevated TC/HDL ratios (>5.00) compared with 11 at discharge. Our results strengthen and expand the findings of three previous studies, which assessed the relation between self-reported activity level and lipid profile. One study found that mobility activities correlated with a more favourable lipid profile.[11] Another study found that only a high level of physical activity was associated with a more favourable lipid profile.[8] In a third study, activity level was only found to be correlated with HDL.[9]

Currently, there is only little attention for everyday physical activity level in most rehabilitation centres. Given the health-related benefits of a higher everyday physical activity level found in our study, we suggest that more attention should be paid to physical activity level during rehabilitation, with the goal of promoting an active lifestyle after discharge from the rehabilitation centre. Everyday physical activity may be promoted by means of behaviour-oriented interventions. There is preliminary evidence for this type of intervention for persons with chronic SCI,[20] but more research is required.

Our study, the first longitudinal study to relate objectively measured physical activity level to physical fitness and lipid profile, in persons with SCI has some limitations. First, the sample size was rather limited, which may influence the ability to generalize our findings. Another consequence is that the number of variables, which could be added to each model was limited. Therefore, we choose to sum the scores of five muscle groups. However, by summing the scores, information about specific muscle groups may be lost. Also, a handheld dynamometer does not cover all the lower ranges of strength. Furthermore, power was limited because of a large number of missing values. Therefore, we were unable to determine possible interaction effects. Unfortunately, in this type of study, missing values are an insurmountable problem. Besides, we looked for a large number of possible correlations, thereby increasing the probability that one of the correlations was significant because of chance. Also, our activity monitor data were limited to 48 h. However, it is suggested that, for measurements with the activity monitor, this is an adequate duration to reliably record activities.[3] Finally, lipid profile can be affected by diet, but we do not have data on the diet of the participants. Besides, there are other risk factors than lipid profile, which might contribute to the risk of cardiovascular disease. However, most of these factors, for example, blood pressure and BMI, are complex in people with SCI because these factors should be interpreted differently compared with the able-bodied population.

DATA ARCHIVING

There were no data to deposit.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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