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

Running head: SCI and the importance of physical activity

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Abstract

Study design. A prospective cohort study.

Objective. To study the longitudinal relationship between objectively measured everyday physical activity level, and physical fitness and lipid profile in persons with a recent SCI.

Setting. A rehabilitation center 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-hours) 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 non-significant relation was found with muscle strength.

Conclusions. Everyday physical activity seems to play 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.

Key words: 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 center 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. While 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, handcycling, 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 4 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 the current 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 2 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 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-hours during 2 consecutive weekdays using an accelerometry-based activity monitor (Vitaport; Temec Instruments, Kerkrade, and Analog devices Nederland, Breda).[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, Kerkrade). 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-hours.

On the 4 test occasions for the 30 participants, a total of 89 measurements of physical activity level were performed. The baseline data on 1 participant could not be measured because the person was wearing a corset during that particular measurement period. The t2-measurement was not performed on 8 participants because the two test occasions (t2 and t3) were too close to one another. The t3-measurement of 4 participants was missing for personal reasons or technical problems with the activity monitor. Three other participants dropped out at t3: 2 died and 1 had personal reasons. Data at t4 were missing for further 12 participants mainly due to personal reasons, and in some cases due to technical problems.

Physical fitness

1. 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). A detailed description of the procedure was given previously.[15]

2. Upper extremity muscle strength

Isometric muscle strength was measured with a handheld dynamometer (Biometrics Europe BV, Almere) using the 'break' testing procedure. [16] The strength (in kN) of 5 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 $mmol \cdot l^{-1}$). 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 4 test occasions. These measures were used to calculate body mass index (BMI in $kg \cdot m^{-2}$).

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, 9 models were made for the course of these different physical fitness and lipid profile parameters. Time was included as 3 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 9 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 more than 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 $p \leq 0.05$.

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 4 test occasions varied between 24.1 ± 4.7 and 24.6 ± 4.2 $kg \cdot m^{-2}$. The t-test, used to test for differences in activity level at t1 between the persons who dropped out (mean=3.55%, SD=2.29) and who had not dropped out at t4 (mean=2.84%, SD=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 non-significant 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 of physical activity level from t1 to t3. At t1 activity level was 3.21%. This level increased with 1.79% to 5.00% at t3. This increase of 1.79% corresponds with 26 minutes/day. For the relation between activity level and VO_2peak, β=0.059. This means that corrected for confounders and time, an increase in physical activity level of 26 minutes/day was associated with an increase of 0.11 $L·min^{-1}$ (β=0.059 * 1.79%) in VO_2peak. The same of 26 minutes/day was, corrected for confounders and time, for power associated with an increase of 4.06 W (β=2.27 * 1.79%), for TG with a decrease of 0.14 $mmol·l^{-1}$ (β=-0.076 * 1.79%) and for TC/HDL ratio with a decrease of 0.23 (β=-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 aerobic capacity (VO_2peak and POpeak). Furthermore, an increase in physical activity level favourably affected 2 of the 6 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 minutes/day was associated with an increase in VO_2peak of 0.11 $L·min^{-1}$. This increase seems clinically relevant, since 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 ambulatory group.[19] It seems that activity level is correlated with aerobic capacity only in persons with a very low aerobic capacity, i.e. wheelchair users who are subject to a sedentary lifestyle.

We found a non-significant 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 $mmol \cdot l^{-1}$) at the start of the study, compared to 2 at discharge from the rehabilitation center. 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 centers. 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 center. Everyday physical activity may be promoted by means of behavior-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, 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 due to 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 due to chance. Also, our activity monitor data was limited to 48 hours. However, it is suggested that, for measurements with the activity monitor, this is an adequate duration to reliably record activities.[3] Lastly, 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, e.g. blood pressure and BMI, are complex in people with SCI since these factors should be interpreted differently compared to the able-bodied population.

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Conflicts of interest statement

The authors declare no conflict of interest.

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Table 1 Group sizes, means and standard deviations of physical activity level and the physical fitness and lipid profile parameters at the 4 test occasions.

	t1 start		t2 3 months later		t3 discharge		t4 year after discharge	
	n	Mean (SD)	n	Mean (SD)	n	Mean (SD)	n	Mean (SD)
Activity level (%)	29	3.21 (2.11)	22	4.98 (2.27)	23	5.00 (2.33)	15	3.51 (3.40)
VO_2peak ($L{\cdot}min^{-1}$)	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 ($mmol{\cdot}l^{-1}$)	28	4.83 (1.08)	26	4.71 (0.96)	29	4.70 (1.03)	17	5.01 (0.98)
HDL ($mmol{\cdot}l^{-1}$)	28	0.99 (0.30)	26	1.15 (0.31)	29	1.20 (0.38)	18	1.17 (0.41)
LDL ($mmol{\cdot}l^{-1}$)	28	3.01 (1.12)	26	3.03 (0.95)	29	2.99 (1.01)	18	3.46 (0.96)
TG ($mmol{\cdot}l^{-1}$)	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)

Activity level: duration of dynamic activities, as a percentage of 24 hours. An activity level of 3.21% corresponds with performing dynamic activities for 46 minutes/day.

Physical fitness: VO_2peak, peak oxygen uptake in $L{\cdot}min^{-1}$; POpeak, peak power output in W; Muscle strength of the upper extremities in kN.

Lipid profile: in $mmol{\cdot}l^{-1}$; TC, total cholesterol; HDL, high-density lipoprotein; LDL, low-density lipoprotein; TG, triglycerides; 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})	.059	.019	.002	.842	.311	-.141	.092	-.171	.098	.059	.113	Gender	-.415	.088
												Lesion level	.072	.366
												Completeness	-.703	.088
												BMI	.017	.009
POpeak (W)	2.27	.758	.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)	.277	.165	.093	19.78	3.47	-2.50	.968	-1.01	.981	.163	1.28	Age	-.035	.027
												Gender	-8.93	.934
												Lesion level	3.18	.817
												Completeness	3.46	.956
												BMI	.296	.093
TC	-.060	.045	.184	5.30	0.36	-.147	.282	-.178	.291	-.235	.347	Lesion level	.072	.219
												Completeness	-.219	.243
HDL	-.017	.016	.289	1.15	.109	-.208	.103	-.035	.106	-.019	.124	Lesion level	.015	.079
LDL	-.054	.045	.230	3.43	.310	-.237	.292	-.172	.302	.026	.351	Lesion level	-.021	.225
TG	-.076	.025	.002	.212	.388	.091	.016	.033	.165	.287	.197	Lesion level	.344	.124
												BMI	.073	.014
TC/HDL	-.127	.061	.038	5.01	.421	.575	.404	-.242	.413	.040	.495	___________		
LDL/HDL	-.098	.057	.087	3.34	.390	.227	.375	-.166	.384	.170	.450	___________		

Abbreviations: VO_2peak, peak oxygen uptake; POpeak, peak power output; TC, total cholesterol; HDL, high-density lipoprotein; LDL, low-density lipoprotein; TG, triglycerides; BMI, body mass index

β indicates the regression coefficient, and s.e. the standard error

t3t1, t3t2, t3t4 indicate time as 3 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.