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ORIGINAL ARTICLE

The longitudinal relationship between lipid profile and physical capacity in persons with a recent spinal cord injury

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Study design: A multicenter prospective cohort study.
Objective: To determine the longitudinal relationship between physical capacity and lipid profile in persons with spinal cord injury (SCI) during and 1 year after rehabilitation.
Setting: Eight Dutch rehabilitation centers with a specialized SCI unit.
Methods: A total of 206 subjects with SCI (78 with tetraplegia) participated. The longitudinal relationship between lipid profiles (total cholesterol (TC), high- (HDL) and low-density lipoprotein (LDL) and triglycerides (TG) and physical capacity (peak power output (POpeak), peak oxygen uptake (VO_2peak), and muscle strength) was investigated during inpatient SCI rehabilitation (start, 3 months later, discharge) and 1 year after discharge. A correction was made for the possible confounding variables age, body mass index, gender, time since injury, lesion level and completeness.
Results: HDL and the ratios LDL/HDL and TC/HDL showed a significant and favorable relationship with VO_2peak, POpeak and muscle strength. TG was positively related to POpeak and muscle strength.
Conclusions: More favorable lipid profiles were seen in people with a higher physical capacity after correction for personal and lesion characteristics. Therefore, improving the physical capacity by being active during daily life or in sport may further improve the lipid profile and thus reduce the risk for coronary heart disease.

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Introduction

Persons with a chronic spinal cord injury (SCI) have a higher mortality rate than the general population.[1] One of the leading causes of death in the chronic SCI population is coronary heart disease.[1] A higher prevalence of coronary heart disease was demonstrated among individuals with an SCI compared to an ambulatory healthy population.[2] A direct relationship between the lipid profile and coronary heart disease has been found in the general population. Several studies reported depressed levels of high-density lipoprotein (HDL)[3–5] and increased levels of low-density lipoprotein (LDL),[6,7] total cholesterol (TC)[6] and triglycerides (TG)[7] in persons with SCI.

Physical fitness, among others, is claimed to have a positive effect on lipid profiles.[8] Persons with an SCI often have a diminished level of activity, mainly due to muscle paralysis, which often leads to a low physical capacity, probably leading to unfavorable lipid profiles. Indeed, active men with an SCI showed significantly higher values for HDL[4,9] and a lower ratio TC/HDL compared to sedentary men with an SCI.[9] Previous findings showed that the amount of physical activity measured 1 year after discharge from inpatient SCI rehabilitation by the physical activity scale for individuals with physical disabilities (PASIPD) was strongly related to the HDL level,[10] but no relationship was found between physical activity, measured by the PASIPD and TC, LDL or TG. The PASIPD is a rough measure for physical activity for people with a disability and, as far as known, is not validated by an external criterion.[11] Since physical activity—a modifiable lifestyle factor—relates to the physical capacity (for example, peak oxygen uptake (VO_2peak)),[9] which is a more accurate measure of actual fitness, it is important to know the relationship between physical capacity and lipid profiles in SCI in more detail.

Our previous studies have focused on the time course of the lipid profile[10] or physical capacity[12] during and 1 year after inpatient SCI rehabilitation. Furthermore, in the past,

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studies have focused on the relationship between physical capacity and the lipid profile in persons with SCI. Some studies concluded that there is a significant relationship between VO_2peak and HDL levels[3,13] or TG, LDL/HDL and TC/HDL.[14] In contrast, Janssen *et al.*[15] did not find a relationship between absolute levels of VO_2 peak and any of the lipid levels in men with a chronic SCI. Isometric strength was found to relate to TC and HDL, while peak power output (POpeak) was related to TG.[16]

The results of these studies provide conflicting evidence. Conclusions are limited in most studies due to a cross-sectional design, and most of the studies only looked at one specific physical capacity parameter, mostly the VO_2peak. Therefore, the purpose of this study was to investigate whether there is a relationship between lipid profile and physical capacity (VO_2peak, POpeak, muscle strength) during and after rehabilitation in a group of subjects with a recent SCI ($n = 206$). It is hypothesized that persons, who have a better physical capacity show a more favorable lipid profile.

Materials and methods

The present study was part of the Dutch research program on the restoration of mobility in persons with SCI. Subjects admitted to one of the eight participating rehabilitation centers between May 2000 and September 2003 were included if they met the eligibility criteria.[17]

All tests and protocols were approved by the Medical Ethics Committee. All subjects completed an informed consent form after which they were given information about the testing procedure.

Design

Within the Dutch multicenter prospective cohort study data were collected at four test occasions: at the start of active rehabilitation (t_1), three months later (t_2), at the end of inpatient rehabilitation (t_3) and 1 year after discharge of inpatient rehabilitation (t_4). In the eight centers, the data were collected by trained research assistants with a paramedical background.

Personal and lesion characteristics

Subject information regarding age, height, gender and time since injury were collected at t_1. The body mass was measured at each test occasion to calculate the body mass index (BMI, body mass per height^2; $\mathrm{kg\,m^{-2}}$). Lesion characteristics (level and completeness) were determined at each test occasion.

Blood lipids

Each test occasion blood samples were taken in the morning, when subjects were in fasting state. TC (in $\mathrm{mmol\,l^{-1}}$) and TG (in $\mathrm{mmol\,l^{-1}}$) concentrations were measured using standardized enzymatic procedures. HDL (in $\mathrm{mmol\,l^{-1}}$) was determined after selective precipitation of the very low-density lipoprotein and LDL fractions; LDL (in $\mathrm{mmol\,l^{-1}}$) was calculated using the Friedewald equation.[18]

Physical capacity

Peak aerobic power output and peak oxygen consumption. To determine peak aerobic power output and peak oxygen consumption subjects performed a graded peak wheelchair exercise test on a motor-driven treadmill.[12] During the first 3-min exercise block, participants propelled the wheelchair with a predetermined velocity of 0.56, 0.83 or $1.11\,\mathrm{m\,s^{-1}}$ and 0° slope of the treadmill. After completion, participants rested for 2 min before starting with the second 3-min exercise block, which was performed at the same velocity and a 0.36° slope of the treadmill. After 2 min of rest the peak exercise test started at the same velocity as the submaximal blocks and a slope of 0.36°. Each minute the slope increased by 0.36° until the participant was unable to continue.

Metabolic cost was continuously measured during the exercise blocks with an Oxycon Delta (Jaeger, Germany). The peak oxygen consumption (VO_2peak; $\mathrm{l\,min^{-1}}$) was defined as the highest oxygen uptake value over 30 s during the test. POpeak was defined by the power output, which corresponded to the highest slope maintained for at least 30 s.[12]

Strength of the upper extremity. To determine the strength of the upper extremities, the shoulder abductors, internal and external rotators, elbow flexors and extensors, and wrist extensors in both arms were tested with the manual muscle test (MMT). The strength was rated on a scale ranging from 0 to 5.[12] The scores of the 12 muscle groups gave an MMT sum score (maximum is 60).

The muscle groups (with exception of the wrist extensors) that scored 3 or greater on the MMT were tested with handheld dynamometry (HHD) according to a standardized protocol.[12] The maximum force (in N) of the 10 muscle groups was summated.

Statistics

Descriptive statistics (means and standard deviations) of personal and lesion characteristics, lipid profiles and physical capacity were calculated for each block and test occasion.

The relationship between lipid profiles and physical capacity were studied using a multilevel regression analysis. The hierarchy in this longitudinal data set can be defined as the repeated measurement occasion over time (level 1), which is grouped within the individual participant (level 2), who are grouped in the different rehabilitation centers (level 3). The regression coefficient of this multilevel regression analysis, has a combined interpretation: (1) The 'cross-sectional' or 'between-subjects' interpretation and (2) the 'longitudinal' or 'within-subject' interpretation.[19]

The dependent variables of this regression analyses were the lipid profiles TC, TG, HDL, LDL, LDL/HDL and TC/HDL at t_1, t_2, t_3 and t_4. The independent variables, the physical capacity parameters (VO_2peak, POpeak, MMTsum and HHDsum), were added separately to the models to study their individual relationship with the lipid profiles. Time since injury (months), age, BMI, gender (male = 0; female = 1), lesion level (tetraplegia (TP) = 0; paraplegia (PP) = 1) and completeness (incomplete = 0; complete = 1) were added to these models to study their possible confounding effect on the relationship between lipid profiles and the physical capacity parameters. If they showed to be a confounder, that is, when the β of the physical capacity parameter changed more than 10% when adding the lesion or personal characteristic, they were added to the final multivariate model. Significance was set at $P<0.05$.

Results

At the start of active rehabilitation the group consisted of 206 participants. Due to several reasons (see De Groot *et al.*[17]), 91 participants of the initial group dropped out during the study, leading to 115 participants 1 year after discharge. Table 1 lists the group sizes, means and standard deviations for the personal and lesion characteristics, the physical capacity parameters and the lipid levels. The mean age of participants at the start of active rehabilitation was 40.4 ± 14.0 years, 73% of the participants was male, 62% of the participants had a PP and 70% had a complete lesion.

Lipid profile and physical capacity

In this longitudinal study, HDL was significantly related ($P \leqslant 0.01$) to all physical capacity parameters when correcting for confounding personal and lesion characteristics (Tables 2 and 3). The ratios LDL/HDL and TC/HDL were significantly related ($P \leqslant 0.03$) to VO_2peak, POpeak and HHDsum. For example, an improvement of VO_2peak from 0.86 to 1.13 $l\,min^{-1}$ (Table 1), that is, an increase of 0.27 $l\,min^{-1}$ was associated with an increase in HDL of 0.03 $mmol\,l^{-1}$ (regression coefficient, 0.111, multiplied by 0.27 $l\,min^{-1}$).

TG was significantly related ($P \leqslant 0.01$) to POpeak and MMTsum. In contrast, LDL and TC did not show a relationship with any of the physical capacity parameters (Tables 2 and 3). All significant relationships were found to be favorable, that is, a higher physical capacity was related to higher HDL levels, lower TG levels and lower LDL/HDL and TC/HDL ratios.

Discussion

Lipid profile and physical capacity

In the present study, HDL was related to all four physical capacity parameters and subsequently the ratios LDL/HDL and TC/HDL showed a significant relationship with all physical capacity measures, except the MMTsum.

In previous cross-sectional studies, HDL also seemed to be associated with activity and physical capacity measures. When sedentary populations with an SCI were compared to active SCI populations, it was shown that HDL[4,9] and VO_2peak[9] were significantly higher in the active group, and subsequently the TC/HDL ratio was lower.[9] Another cross-sectional study[14] on nine male subjects with a PP showed that VO_2peak measured during arm-crank exercise, was moderately related to HDL ($r=0.47$) although an expected inverse relationship with TC/HDL ($r=-0.86$) and LDL/HDL ($r=-0.72$) was found.[14] Finding only a moderate relationship between HDL and VO_2peak might be explained by the absence of correction for possible confounding variables in these results.[14]

Our previous study[10] on lipid profile in SCI indicated that physical activity over the past 7 days (measured by the PASIPD questionnaire) related to HDL only, but not to the other lipid variables. The suggestion was made that physical capacity parameters, which are more accurate measures of actual fitness, might show a stronger relationship with the different lipid profiles.

Indeed a relationship between TG and the physical capacity parameters POpeak and MMTsum was found. That TG was related to physical capacity was shown before in the longitudinal study of Dallmeijer *et al.*[16] They found an inverse relationship between TG and VO_2peak and POpeak (expressed in $W\,kg^{-1}$). Also, cross-sectional results indicated that TG was related to the VO_2peak ($r=-0.73$), measured in an arm-crank exercise test.[14]

In contrast to HDL and TG, LDL and TC were not related to any of the physical capacity parameters in the present study. This is to some extend in agreement with the study of Bostom *et al.*,[14] who found moderate correlations between VO_2peak and TC ($r=-0.51$) and LDL ($r=-0.48$), but in contrast to Dallmeijer *et al.*,[16] who found a relationship between TC and isometric strength.

The present study only found a relationship between physical capacity and HDL (and the ratios that include HDL) and TG. This might be explained by the previously found strong inverse correlation between TG and HDL.[3] The inverse relationship between HDL and TG was also supported by Maki *et al.*[5] and Janssen *et al.*[15] ($r=-0.67$). Bauman *et al.*[3] suggested that this inverse relationship may reflect the effects of plasma insulin, that may be elevated as a consequence of reduced peripheral insulin sensitivity, on lipid metabolism. Hyperinsulinemia may cause increased hepatic TG production, which in turn, tends to lower HDL possibly by enhancing clearing mechanisms.[3]

A significant positive correlation was found between maximal oxygen consumption and insulin sensitivity in a group with a recent SCI.[20] This might indicate that those with a higher VO_2peak have a better insulin sensitivity and, therefore, show lower TG and higher HDL levels.

Another explanation for the effect of exercise/physical capacity on the lipid profile lies in the catecholamines concentrations. Persons with an SCI have a disturbed catecholamines regulation,[7]that is, lower epinephrine (Epi) and norepinephrine (NE) concentrations in rest. Schmid *et al.*[21] showed that the lower the NE values, the lower HDL and that LDL also correlated to catecholamines. However, during exercise there is a slight increase in these concentrations in TP and high PP.[22] People with an SCI with a higher physical capacity might be more involved in exercise, which leads to a temporary increase in Epi and NE, and subsequently a more favorable lipid profile.

Training

Arm-crank exercise training (12 weeks, 60–65%VO_2peak, 30 min) in individuals with SCI showed to be favorable as reflected by a significant increase in VO_2peak and an increase

Table 1 Raw data (mean ± s.d. or counts) for lesion, personal and lifestyle characteristics and the lipid profiles of the person group at study

Variables	*Start*		*3 months*		*Discharge*		*Year after discharge*	
	n	*Mean ± s.d.*	n	*Mean ± s.d.*	n	*Mean ± s.d.*	n	*Mean ± s.d.*
Time since injury (months)								
TP	77	3.0 ± 1.8	65	6.9 ± 2.5	61	13.0 ± 6.1	30	25.5 ± 6.2
PP	127	3.0 ± 2.1	78	6.5 ± 2.4	105	8.9 ± 3.6	83	21.7 ± 4.5
Age (years)								
TP	77	38.5 ± 12.8	65	40.2 ± 13.2	62	41.1 ± 13.2	30	42.1 ± 13.6
PP	128	41.5 ± 14.7	79	42.2 ± 15.2	105	41.5 ± 14.8	84	41.1 ± 14.2
BMI								
TP	74	22.4 ± 4.3	63	23.1 ± 4.6	60	23.5 ± 4.2	30	24.7 ± 4.3
PP	120	23.1 ± 3.6	76	23.4 ± 3.6	100	23.7 ± 4.0	83	24.5 ± 4.5
Men (%)								
TP	78	72%	65	71%	62	74%	30	63%
PP	128	74%	79	78%	105	73%	84	73%
Complete (%)								
TP	77	66%	63	60%	59	53%	28	54%
PP	127	72%	78	73%	103	70%	81	75%
VO_2peak ($l \cdot min^{-1}$)								
TP	21	0.86 ± 0.24	20	0.80 ± 0.29	33	1.01 ± 0.38	13	1.13 ± 0.44
PP	82	1.07 ± 0.37	67	1.20 ± 0.37	89	1.29 ± 0.43	65	1.36 ± 0.54
POpeak (W)								
TP	23	16.3 ± 9.0	21	16.5 ± 7.2	34	25.2 ± 16.3	12	31.4 ± 22.6
PP	81	34.6 ± 17.7	67	43.0 ± 19.2	90	47.4 ± 21.9	66	51.1 ± 24.7
MMTsum								
TP	65	40.4 ± 14.8	57	42.3 ± 13.2	56	46.1 ± 13.4	29	47.6 ± 13.2
PP	105	57.9 ± 4.7	74	58.9 ± 3.5	99	59.1 ± 2.5	82	58.7 ± 4.25
HHDsum (n)								
TP	27	1107 ± 455	28	1282 ± 456	31	1508 ± 466	19	1425 ± 658
PP	85	1673 ± 477	60	1827 ± 504	71	1907 ± 499	54	1990 ± 519
HDL ($mmol\,l^{-1}$)								
TP	78	0.96 ± 0.27	65	1.11 ± 0.30	62	1.14 ± 0.32	30	1.37 ± 0.50
PP	127	1.05 ± 0.32	79	1.12 ± 0.30	104	1.18 ± 0.39	85	1.18 ± 0.35
LDL ($mmol\,l^{-1}$)								
TP	77	2.86 ± 0.77	64	2.84 ± 0.95	62	2.95 ± 0.87	30	3.03 ± 0.88
PP	125	3.10 ± 1.07	79	2.97 ± 0.83	101	2.86 ± 0.89	82	3.13 ± 1.02
TC ($mmol\,l^{-1}$)								
TP	78	4.48 ± 1.05	65	4.68 ± 1.05	62	4.70 ± 0.98	29	4.98 ± 1.01
PP	128	4.90 ± 1.20	80	4.70 ± 0.99	106	4.70 ± 1.07	85	4.97 ± 1.19
TG ($mmol\,l^{-1}$)								
TP	78	1.64 ± 0.90	65	1.64 ± 1.01	62	1.40 ± 0.67	29	1.37 ± 0.89
PP	128	1.68 ± 1.10	80	1.48 ± 0.95	106	1.58 ± 1.09	85	1.63 ± 1.08
LDL/HDL								
TP	77	3.19 ± 1.25	64	2.80 ± 1.42	62	2.79 ± 1.20	30	2.57 ± 1.30
PP	125	3.14 ± 1.31	79	2.87 ± 1.18	101	2.74 ± 1.38	82	2.92 ± 1.39
TC/HDL								
TP	78	4.98 ± 1.69	65	4.57 ± 1.85	62	4.41 ± 1.52	29	4.12 ± 1.66
PP	127	4.96 ± 1.65	79	4.44 ± 1.43	104	4.38 ± 1.89	85	4.54 ± 1.72

Abbreviations: BMI, body mass index; HDL, high-density lipoprotein; HHDsum, sum score of the handheld dynamometry; LDL, low-density lipoprotein; *MMTsum*, sum score of the manual muscle test; *POpeak*, peak power output; PP, paraplegia; TC, total cholesterol; TG, triglycerides; TP, tetraplegia; *VO_2peak*, peak oxygen uptake.

in power output, which occurred in parallel with a marked increase in HDL, whereas TC and TG were not altered.[23] However, 3 months of exercise training (resistance and endurance exercise of the upper extremities, 3 times per week) in men with chronic PP showed an increase in VO_2peak, POpeak, HDL and a decrease in LDL/HDL,

Table 2 The multivariate regression models for the relationship between VO_2peak and POpeak and different lipid profiles

	HDL			*LDL*			*TC*			*TG*			*LDL/HDL*			*TC/HDL*		
	β	*s.e.*	P	*β*	*s.e.*	P	*β*	*s.e.*	P	*β*	*s.e.*	P	*β*	*s.e.*	P	*β*	*s.e.*	P
VO_2peak (l min^{-1})																		
Constant	0.890	0.057		1.519	0.396		2.487	0.436		−0.492	0.332		0.962	0.504		1.558	0.604	
VO_2peak (l min^{-1})	0.111	0.043	0.01	−0.214	0.130	0.42	−0.115	0.142	0.42	−0.139	0.104	0.18	−0.420	0.161	<0.01	−0.433	0.196	0.03
TSI (months)[a]	0.006	0.002	<0.01	0.008	0.005	0.11	0.011	0.005	0.03	—	—		−0.008	0.006	0.18	−0.015	0.008	0.06
Age (years)	—	—		0.012	0.005	0.02	0.016	0.006	<0.01	0.003	0.005	0.55	—	—		0.002	0.008	0.80
BMI	—	—		0.041	0.015	0.01	0.059	0.017	<0.01	0.080	0.013	<0.01	0.101	0.020	<0.01	0.151	0.025	<0.01
Gender[b]	0.194	0.052	<0.01	0.189	0.157	0.23	0.407	0.174	0.02	0.165	0.142	0.25	—	—		—	—	
Lesion level[c]	—	—		0.180	0.137	0.19	0.268	0.151	0.08	0.158	0.118	0.18	—	—		—	—	
Completeness[d]	—	—		−0.023	0.109	0.83	−0.071	0.119	0.55	—	—		0.175	0.143	0.22	—	—	
POpeak (W)																		
Constant	0.918	0.043		1.397	0.377		2.408	0.416		−0.642	0.349		0.684	0.509		1.223	0.618	
Popeak (W)	0.003	0.001	<0.01	−0.003	0.003	0.32	0.0004	0.003	0.90	−0.005	0.002	0.01	−0.009	0.004	0.02	−0.011	0.004	<0.01
TSI (months)[a]	0.005	0.002	0.01	0.006	0.005	0.23	0.007	0.005	0.16	—	—		−0.008	0.006	0.18	−0.017	0.008	0.03
Age (years)	—	—		0.013	0.005	<0.01	0.017	0.006	<0.01	0.003	0.005	0.55	0.003	0.007	0.67	0.0003	0.008	0.97
BMI	—	—		0.039	0.015	<0.01	0.057	0.017	<0.01	0.085	0.015	<0.01	0.098	0.021	<0.01	0.153	0.025	<0.01
Gender[b]	0.198	0.051	<0.01	0.193	0.155	0.21	0.418	0.170	0.01	0.265	0.158	0.10	—	—		—	—	
Lesion level[c]	—	—		0.166	0.142	0.24	0.232	0.156	0.14	0.242	0.127	0.06	0.150	0.190	0.43	0.189	0.231	0.41
Completeness[d]	—	—		−0.009	0.106	0.93	−0.046	0.117	0.70	—	—		0.174	0.141	0.22	0.246	0.173	0.16

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 and s.e. the standard error.

[a] TSI, time since injury.

[b] Male = 0; female = 1.

[c] Tetraplegia = 0; paraplegia = 1.

[d] Incomplete = 0; complete = 1.

Table 3 The multivariate regression models for the relationship between the sum score of the manual muscle test (MMTsum) and handheld dynamometry (HHD) and different lipid profiles

	HDL			*LDL*			*TC*			*TG*			*LDL/HDL*			*TC/HDL*		
	β	*s.e.*	P	*β*	*s.e.*	P	*β*	*s.e.*	P	*β*	*s.e.*	P	*β*	*s.e.*	P	*β*	*s.e.*	P
MMT																		
Constant	0.774	0.089		1.120	0.346		2.148	0.400		0.364	0.380		1.192	0.481		2.246	0.623	
MMTsum	0.006	0.002	<0.01	0.004	0.004	0.32	0.008	0.005	0.11	−0.015	0.005	<0.01	−0.010	0.007	0.15	−0.017	0.009	0.06
TSI (months)[a]	0.007	0.001	<0.01	0.003	0.003	0.32	0.005	0.004	0.21	−0.009	0.003	<0.01	−0.015	0.005	<0.01	−0.025	0.006	<0.01
Age (years)	—	—		0.011	0.004	<0.01	0.020	0.005	<0.01	0.010	0.005	0.04	—	—		—	—	
BMI	—	—		0.046	0.012	<0.01	0.057	0.014	<0.01	0.067	0.013	<0.01	0.096	0.016	<0.01	0.141	0.021	<0.01
Gender[b]	—	—		0.166	0.125	0.18	—	—		—	—		—	—		—	—	
Lesion level[c]	−0.049	0.043	0.25	—	—		—	—		0.187	0.120	0.12	0.158	0.160	0.32	0.195	0.209	0.35
Completeness[d]	—	—		—	—		—	—		—	—		—	—		—	—	
HHD (n)																		
Constant	1.209	0.138		1.614	0.399		2.602	0.436		−0.342	0.414		1.302	0.540		2.077	0.670	
HHDsum	0.0001	0.00004	<0.01	−0.0001	0.0001	0.32	−0.00004	0.0001	0.77	−0.0002	0.0001	0.32	−0.0005	0.0002	0.01	−0.0007	0.0002	<0.01
TSI (months)[a]	0.009	0.002	<0.01	0.006	0.005	0.23	0.010	0.006	0.10	—	—		−0.009	0.007	0.20	−0.018	0.008	0.02
Age (years)	0.007	0.002	<0.01	0.012	0.005	0.02	0.019	0.005	<0.01	0.007	0.005	0.16	0.001	0.007	0.89	0.000	0.008	1.00
BMI	−0.029	0.005	<0.01	0.040	0.015	<0.01	0.052	0.017	<0.01	0.072	0.016	<0.01	0.094	0.021	<0.01	0.147	0.026	<0.01
Gender[b]	0.276	0.056	<0.01	0.043	0.157	0.79	0.362	0.171	0.03	0.189	0.171	0.27	−0.615	0.216	<0.01	−0.730	0.265	<0.01
Lesion level[c]	−0.079	0.049	0.11	0.203	0.143	0.16	0.227	0.157	0.15	0.315	0.150	0.04	—	—		0.467	0.239	0.05
Completeness[d]	—	—		0.037	0.104	0.73	−0.075	0.114	0.50	−0.012	0.105	0.91	0.334	0.137	0.02	0.365	0.171	0.03

Abbreviations: BMI, body mass index; HDL, high-density lipoprotein; HHD, handheld dynamometry; HHDsum, sum score of the handheld dynamometry; LDL, low-density lipoprotein; MMT, manual muscle test; *MMTsum*, sum score of the manual muscle test; TC, total cholesterol; TG, triglycerides.

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

[a] TSI, time since injury.

[b] Male = 0; female = 1.

[c] Tetraplegia = 0; paraplegia = 1.

[d] Incomplete = 0; complete = 1.

TC/HDL as well as in LDL.[24] Differences in results between studies could also be due to differences in form of exercise and intensity, duration and frequency. An arm training study showed that TC/HDL and TG decreased significantly more in an 8-week high-intensity training group (70–80% HRR (heart rate reserve)) compared to a low-intensity training group (40–50% HRR).[20] Changes in TC, HDL and LDL did not differ between the two intensity groups.[20]

Limitations of the study

The present study had some limitations. Specific inclusion criteria such as 18–65 years of age and wheelchair dependent, which led to a relatively high number of people with a complete lesion, makes it impossible to generalize the results of this study to all persons with an SCI.[17]

Some of the analyses represented a positive selection of all persons with an SCI. The participants who could perform the wheelchair peak exercise test were not limited by cardiovascular or musculoskeletal complaints and were able to propel the wheelchair at least at $0.56\,\mathrm{m\,s^{-1}}$ for 3 min. A positive selection was made for the HHD measurement since only participants with an MMT score $\geqslant 3$ were able to perform the HHD muscle force testing. By using sum scores, some information might be lost.

The present results showed a significant relationship between physical capacity and HDL, TC/HDL, LDL/HDL and TG: an increase of for example, $\mathrm{VO_2}$peak with $0.27\,\mathrm{l\,min^{-1}}$ was associated with a very small increase in HDL of $0.03\,\mathrm{mmol\,l^{-1}}$ This might not be seen as a clinical relevant change. However, together with the results of the above-described (training) studies, it seems that improvement of the physical capacity by being active during rehabilitation, daily life or in sport activities may improve the lipid profile and thus reduce some of the risk factors for coronary heart disease in persons with a recent SCI. Furthermore, it is important to keep in mind that other lifestyle factors, such as dietary intake, have an effect on the lipid levels as well.

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