

Original Article

Effect of training intensity on physical capacity, lipid profile and insulin sensitivity in early rehabilitation of spinal cord injured individuals

PCE de Groot^{*1}, N Hjeltnes², AC Heijboer³, W Stal³ and K Birkeland⁴

¹Department of Physiology, University Medical Centre Nijmegen, the Netherlands; ²Sunnaas Hospital, Nesoddtangen, Norway; ³Free University Amsterdam, Faculty of Human Movement Sciences, the Netherlands; ⁴Department of Endocrinology, Aker University Hospital, Oslo, Norway

Study design: Pre–post training intervention.

Objectives: To evaluate the effect of training intensity on physical capacity, lipid profile and insulin sensitivity in early rehabilitation of spinal cord injured (SCI) patients, and to assess the correlation between peak aerobic capacity (VO^{2Peak}) and insulin sensitivity.

Setting: Spinal Cord Rehabilitation Unit, Sunnaas Hospital, Nesoddtangen, Norway.

Method: Six recently injured SCI individuals participated in the arm training intervention and were randomly admitted to a high-intensity (HI; 70–80% heart rate reserve (HRR)) and low-intensity (LI; 40–50% HRR) group. The 1 h interval training consisted of 3 min exercise bouts interspersed with 2 min of rest, three times a week for 8 weeks. In addition, a correlation coefficient was obtained between VO^{2Peak} and insulin sensitivity in 11 SCI patients.

Results: The 8-week training program resulted in a significant increase in VO^{2Peak} and maximal power output (PO^{Max}) for the group as a whole ($P < 0.05$). VO^{2Peak} increased significantly more and total cholesterol/high-density lipoprotein cholesterol (TC/HDL-C) ratio and triglycerids decreased significantly more in the HI group than in the LI group ($P = 0.05$). Training-induced changes in insulin sensitivity were significantly different between the groups ($P = 0.05$), which was due to a nonsignificant decline in insulin sensitivity in the HI group and a nonsignificant improvement in the LI group. A significant positive correlation was found between VO^{2Peak} and insulin sensitivity ($r = 0.68$, $P = 0.02$).

Conclusion: The interval arm training protocol as used in the present study enables recently injured SCI patients to do substantial work at a relatively high intensity. Results indicate that improvements in physical capacity and lipid profile were more pronounced in response to high-intensity training. The significant correlation between maximal oxygen consumption and insulin sensitivity indicates that, as in the able-bodied population, peak aerobic capacity is a predictive value with regard to insulin sensitivity in SCI. Future studies with larger groups assessing the role of exercise intensity on insulin sensitivity in SCI are suggested.

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Keywords: training intensity; early SCI; insulin sensitivity; VO^{2Peak} ; arm exercise

Introduction

A spinal cord injury (SCI) disrupts the nervous connections in the spinal cord and results in muscle paralysis, loss of sensation and autonomic dysfunction below the level of injury. In addition, well-known risk factors for cardiovascular diseases such as glucose intolerance, disturbances in lipid profile, alterations in body composition and morphological changes in skeletal muscles are observed in higher proportion in persons with long-term SCI.^{1–6} It is most likely that these

profound metabolic alterations are related to the extreme physical inactivity, which is a direct consequence of the injury.⁷ Increasing physical activity may therefore play an important role in reducing these cardiovascular risk factors in SCI. In addition, physical exercise is needed if persons with SCI are to reach and maintain the level of physical fitness that is desirable for their function in daily life. Therefore, the effort to achieve optimal levels of physical fitness should start during primary rehabilitation itself. Numerous studies in able-bodied individuals have documented the health benefits of physical training.^{8–10} In the able-bodied

*Correspondence: PCE de Groot, Department of Physiology, UMC St Radboud, PO Box 9101, 6500 HB Nijmegen, The Netherlands

population, health-related metabolic improvements are generally considered to be more pronounced in response to high-intensity exercise than to moderate to low-intensity exercise.^{11,12} However, only little is known about the most optimal training intensity in persons with SCI, and it is not known whether recently injured SCI persons can sustain a relatively high physical strain in early rehabilitation.

The use of arm exercise modes as used in SCI incorporates a relatively small muscle mass. The primary factors that limit performance during exercise may be peripheral in nature and local fatigue of the highly stressed arm musculature can occur despite sufficient systemic availability of blood and oxygen. Also, circulatory responses to exercise differ in spinal cord-injured individuals compared with able-bodied individuals as a result of a disturbed redistribution of blood.^{13,14} Maximal aerobic capacity (VO_2^{Peak}) is a predictive value with regard to insulin sensitivity in the able-bodied population, and a highly significant positive correlation between VO_2^{Peak} and insulin sensitivity has been reported.^{15,16} It is not known if there is also such a relationship in the spinal cord-injured population. The main purpose of the present study was to assess the effect of two different exercise intensities on insulin sensitivity, physical capacity and lipid profile during early rehabilitation in persons with SCI. In addition, a correlation coefficient was obtained between VO_2^{Peak} and insulin sensitivity. To our knowledge, this is the first study to investigate these topics during the early phase following a SCI.

Methods

Subjects

Training intervention Six SCI individuals (four males and two females) participated in the training intervention. All of them were wheelchair users. They were admitted for primary rehabilitation and their level of

lesion varied from C5 to L1. Individual subject characteristics are shown in Table 2. Subjects known to have cardiovascular diseases and diabetes were excluded from the study. Group subject characteristics are presented in Table 1.

Correlation study A total of 11 wheelchair bound SCI individuals admitted for primary rehabilitation were willing to participate in the correlation study. The level of lesion varied from C5 to L1. The same exclusion criteria as mentioned above were applied for the correlation study. Individual subject characteristics are presented in Table 2.

The study protocol was reviewed and approved by the Regional Ethics Committee and all subjects provided written, informed consent.

Design

Training intervention The subjects were randomly admitted to a low-intensity (LI) or high-intensity (HI) training protocol. The training programs for both intensity groups consisted of a 1-h interval group training, three times a week for a period of 8 weeks. The different intensities were 70–80% of the heart rate reserve (HRR) in the HI group and 40–50% HRR in the LI group. This training intervention was conducted in

Table 1 Subject characteristics HI and LI group

	HI Group	LI Group
Number of subjects	3	3
Gender (female/male)	0/3	2/1
Age (years)	39 (2)*	52 (2)
Body mass (kg)	80 (13)	65 (9)
Body height (cm)	180 (6)	168 (10)
Time since injury (days)	92 (72)	116 (94)

Values are presented as mean (SD). * $P < 0.05$

Table 2 Individual characteristics in the correlation study

Subjects (intervention study)	Age (years)	Sex	Level of lesion (ASIA score)	Time since injury (days)	Body mass (kg)	Body height (cm)
1 (HI)		M	T8 (C)	43	88	182
2	20	M	T4 (A)	122	73	186
3 (LI)	54	F	L1 (C)	61	70	166
4	43	M	T10 (A)	320	90	185
5	40	M	C5 (D)	60	58	178
6 (HI)	38	M	C5 (A)	175	89	186
7	22	F	T1 (A)	147	68	172
8 (LI)	51	F	L1 (C)	225	55	160
9 (LI)	50	M	T3 (C)	63	70	179
10 (HI)	38	M	L1 (B)	58	65	174
11	19	M	L1 (C)	30	64	183
Mean (SD)	36 (13)			116 (77)	68 (11)	176 (9)

Subject 1, 3, 6, 8, 9 and 10 are participants in the intervention study, HI: high-Intensity group, LI: low-Intensity group

addition to the usual daily rehabilitation program. Patients were evaluated on their physical work capacity as soon as they were able to sit in a wheelchair and carry out vigorous arm exercise. Insulin sensitivity and lipid profile were also determined during the same week. After 8 weeks of training, all subjects were retested at the same point of time according to the same protocol as used in the pretest.

Correlation study All subjects underwent an insulin sensitivity test followed by an exercise test in the same week. Pretraining measurements of VO_2^{Peak} and insulin sensitivity from the six subjects participating in the intervention study were also used for analyses in the correlation study.

Test protocol

Physical capacity The arm exercise test consisted of a discontinuous graded exercise protocol using a calibrated ergometer 800 (Ergoline, Germany). Generally, 3 min of arm cranking were separated by 2 min of rest. Blood pressure was measured (9300, Paramed) immediately after each exercise bout. The power output was increased with equal steps. The average power output at the start was 16 W with a standard deviation of 7 W. The cycling rate had to be kept constant in the range between 60 and 70 rotations per minute. The exercise test was ended when the subject could no longer sustain the pace in spite of verbal encouragement. Heart rate (HR) and power output (PO watts) were measured continuously. Oxygen uptake (VO_2 , l/min and ml/kg/min) was measured breath-to-breath during the exercise test and the highest value averaged over 30 s was taken as VO_2^{Peak} (Vmax 229, SensorMedics).

Insulin sensitivity The HOMA-CIGMA test^{17,18} was used to measure insulin sensitivity. Subjects were instructed to refrain from exercise for 48 h and they were tested after an overnight fast in supine position. Intravenous catheters were inserted into elbow veins in both arms. Three blood samples were drawn at -15, -10 and -5 min through a Venflon catheter (1.2 × 32 mm, Becton Dickinson) for glucose and insulin analyses. At 0 min, subjects were administered to a continuous intravenous infusion of 5 mg glucose/kg ideal body weight/min during 1 h (Metropolitan Height-Weight Tables, 1983). At 50, 55 and 60 min after the start of the infusion, three venous blood samples were withdrawn for analyses of glucose and insulin. Blood glucose concentration was determined directly after sampling (Vitros 250, Johnson & Johnson, Ortho Clinical Diagnostics). Blood plasma samples were frozen (-30°C) for further insulin analyses. Insulin was measured using a competitive RIA (Linco Research Inc. St Charles, MO, USA).

Lipid profile From fasting blood samples, total cholesterol (TC), high-density lipoprotein cholesterol

(HDL-C) and triglycerides (TG) were obtained (Vitros 250, Johnson & Johnson, Ortho Clinical Diagnostics). Low-density lipoprotein cholesterol (LDL-C) was calculated by Friedewald's formula.¹⁹

Training session

For the HI and the LI groups, the 1-h training sessions contained the same protocol, only the intensities differed. The sessions aimed at maintaining the HR between 50–60 or 70–80% of HRR,²⁰ for 20 min.

$$HRR = \frac{HR_{act} - HR_{rest}}{HR_{peak} - HR_{rest}} \times 100\%$$

The resting heart rate was measured during rest early in the morning on one occasion before the training program had started. The peak heart rate was derived from the pretest peak exercise arm-crank test. The training consisted of arm-cranking, in intervals of 3 min cranking and 2 min of rest. In order to prevent the training from becoming monotonous, the arm-cranking was interchanged with exercises such as boxing, push-ups and ball throwing. At all sessions, the heart rate was monitored with Polar sport tester.

Statistics

Statistical analyses were performed using SPSS 8.0. The heterogeneity of the groups and the small number of subjects demanded that nonparametric statistics be used. Owing to the large interpersonal differences, data in the intervention study were taken relative to the initial state ((post-test values/pretest values) × 100%). A Wilcoxon-signed rank test was used to compare pre- and post-training values. Differences between HI and the LI group were compared using a Mann-Whitney *U*-test. To study the association between the insulin sensitivity and peak aerobic capacity, a correlation analysis was carried out with a Spearman rank-difference correlation. The level of significance for all tests was at *P*-value 0.05.

Results

Subject characteristics like body mass, body height and time since injury did not differ between the groups. Age was significantly lower in the HI group. The results of pretraining measurements on physical capacity, lipid profile and insulin sensitivity did not differ between the groups.

Training intervention

The 8-week training program resulted in a significant increase in VO_2^{Peak} and PO^{Max} for the group as a whole ($P < 0.05$). The individual absolute results on VO_2^{Peak} , PO^{Max} , insulin sensitivity and lipid profile parameters are presented in Figure 1. Post-test values relative to pre-test values of both intensity groups are presented in Table 3. It is shown that VO_2^{Peak} increased significantly more, and triglycerides and TC/HDL ratio decreased significantly more in the HI group than in the LI group

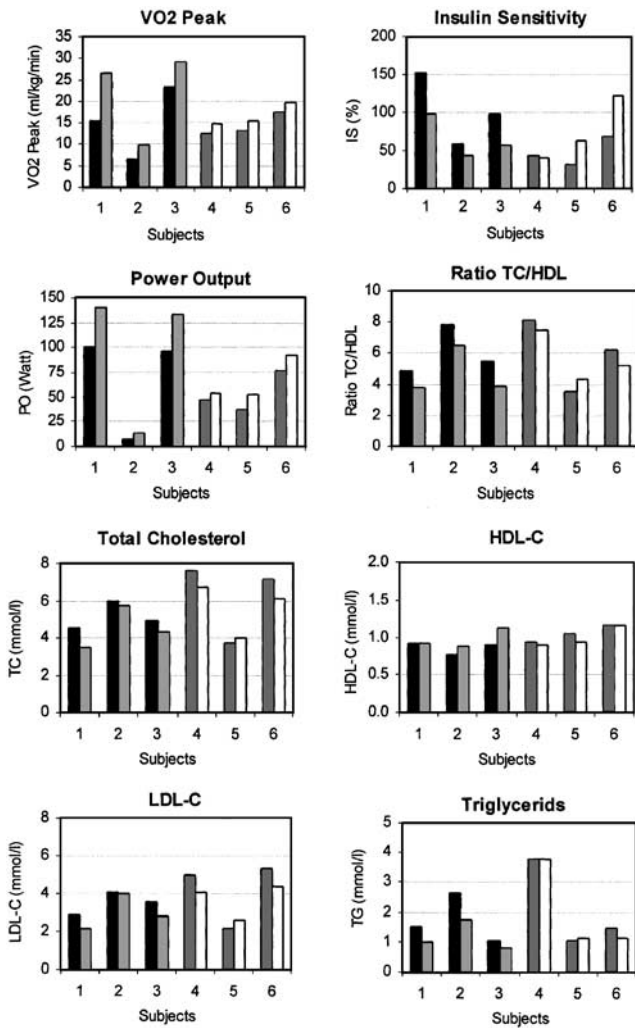


Figure 1 Individual absolute pre- and post-test values for VO_2^{Peak} , power output (PO), insulin sensitivity (IS), ratio total cholesterol/high-density lipoprotein cholesterol (TC/HDL-C), TC, HDL-C, low-density lipoprotein cholesterol (LDL-C) and triglycerides (TG). HI: high-intensity group. LI: low-intensity group. ■ Pre-Training HI ■ Pre-Training LI □ Post-Training HI □ Post-Training LI.

Table 3 Post-test values relative to the pretest values expressed as a percentage (SD) for the high-intensity (HI) and low-intensity (LI) group. (* $P < 0.05$)

	HI group	LI group
VO_2^{Peak}	150 (24)*	117 (4)
PO^{Max}	159 (33)	124 (13)
Insulin sensitivity	67 (9)*	156 (55)
Total cholesterol	87 (9)	94 (13)
HDL	113 (12)	95 (6)
LDL	86 (9)	95 (22)
Ratio TC/HDL	77 (6)*	100 (20)
Triglycerides	69 (7)*	95 (14)

($P = 0.05$). Furthermore, results show a significant difference between the groups for insulin sensitivity ($P = 0.05$), which was due to a nonsignificant decrease in insulin sensitivity in the HI group and a nonsignificant improvement in the LI group. The increase in PO^{Max} and the changes in lipid profile parameters TC, HDL and LDL did not differ between the two groups.

Correlation study

The Spearman correlation coefficient revealed a significant correlation between VO_2^{Peak} and insulin sensitivity ($r = 0.68$; $P = 0.02$; Figure 2).

Discussion

In the present study, we evaluated the effect of training intensity on physical capacity, lipid profile and insulin sensitivity in early rehabilitation of SCI individuals. In addition, a group of SCI individuals in primary rehabilitation was studied at a single time point to assess the correlation between peak aerobic capacity (VO_2^{Peak}) and insulin sensitivity.

Physical capacity

Results of the present study show that 8 weeks of arm exercise training induces a significant increase in cardiopulmonary fitness (VO_2^{Peak}) and maximal power output (PO^{Max}) for the group as a whole. Improvements in VO_2^{Peak} were more pronounced in response to HI training, that is, post-training levels were 150% for the HI group and 117% in the LI group. In addition, a trend towards a greater increase in PO^{Max} was found for the HI group (159 versus 124%). These findings in our fairly recently injured SCI individuals are in line with previous studies assessing the effect of arm training intensity on physical capacity in able-bodied subjects²¹ and long-term spinal cord-injured individuals.²²

Lipid profile

Evidence suggests that cardiovascular diseases, particularly coronary heart disease (CHD), are the leading

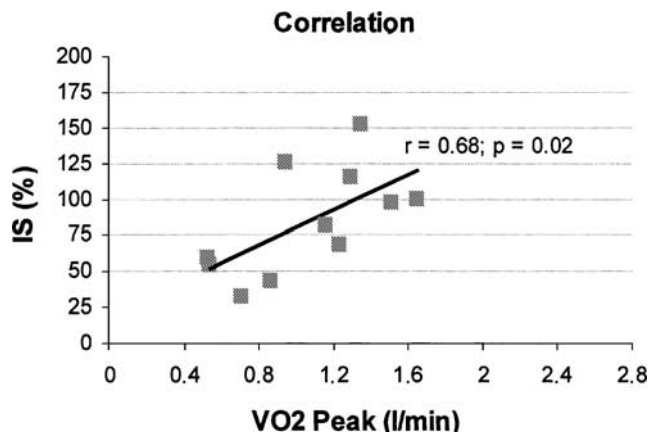


Figure 2 Correlation between VO_2^{Peak} and insulin sensitivity.

cause of death in the chronic spinal cord injured population.²³ Previous studies reported unfavourable lipid and (apo) lipoprotein profiles in persons with SCI.^{4,7} It has been suggested that the low levels of HDL-C concentrations are the consequence of the extremely low levels of physical activity in the SCI population, mainly as a result of their wheelchair-dependent life.^{2,7} Indeed, earlier studies have demonstrated that highly trained SCI subjects had more favourable lipid profiles than untrained SCI subjects, indicating an important role for physical activity.⁴ In the present study, it was found that the ratio TC/HDL-C, which is considered to be a stronger predictor of CHD than HDL-C alone,²⁴ and TG decreased significantly more in the HI group than in the LI group. Although a positive trend can be seen, the changes in TC, HDL-C and LDL-C did not differ between the two intensity groups. Findings of the present study in relatively acute SCI individuals are in agreement with a previous study assessing the effect of low (50–60% HRR) and moderate training intensity (70–80% HRR) on lipid profile in chronic SCI individuals.²² The authors demonstrated that blood lipid levels remained unaltered in the LI group, while the moderate-intensity group exhibited significant increases in HDL-C and decreases in TG, LDL-C and TC/HDL-C ratio.

Insulin sensitivity

Chronic SCI individuals are characterized by alterations in body composition and muscle morphology, glucose intolerance and a decreased whole-body insulin sensitivity.^{5,25,26} These metabolic disturbances are thought to contribute to the increased risk for cardiovascular diseases (CVD) in this group. Numerous previous investigations have shown the beneficial effects of physical training on insulin sensitivity in both healthy and glucose-intolerant subjects.⁸ Hjeltnes *et al*²⁷ assessed the effect of 8 weeks of electrically stimulated leg cycling (ESLC) in chronic tetraplegics and reported an increase in whole-body insulin sensitivity and an increase in protein expression of key genes involved in glucose metabolism. In agreement with these findings, other recent studies in chronic SCI individuals demonstrated similar beneficial results of electrically induced cycle training on insulin sensitivity and glucose tolerance.^{28,29}

In our study, the HOMA-CIGMA test was used to assess insulin sensitivity. This model has been shown to be a reliable, easy, quick and low-cost method, has a good test–retest reliability and can be used to detect changes on the individual level.^{17,30} Findings of the present study indicate that the arm exercise training induced a significant difference in insulin sensitivity between the LI group and the HI group. In contrast to what we expected, this difference between the groups was due to a nonsignificant decrease in insulin sensitivity in the HI group and a nonsignificant increase in insulin sensitivity in the LI group. These results are contrary to the accepted dogma in the literature and not in agreement with a previous study assessing the role of

exercise intensity on insulin sensitivity in a group of 18 healthy able-bodied subjects.¹² Borghouts *et al* reported that improvements in insulin sensitivity were more pronounced in response to 4 weeks of HI interval training than to LI interval training. Their training protocol consisted of 3 min exercise bouts interspersed with 2 min at a lower intensity on a bicycle ergometer, with intensities 80–40% of pre-training maximal power output (W_{\max}) in the HI group and 40–20% W_{\max} in the LI group.¹²

It seems evident that results of our study must be viewed with cautions due to several factors. First of all, the small sample size in the present study with only three subjects per intervention group is obviously too small to draw firm conclusions. Furthermore, subjects in the intervention differed in age, sex, level and completeness of injury, which may all influence the results. In addition, in the early phase after an SCI, there are several variables that might affect insulin sensitivity by release of counter regulatory hormones. Although the differences in pretraining values of insulin sensitivity were not significant, it seems that the HI group had the most insulin-sensitive individuals at baseline (HI: 103 ± 46 versus LI: $48 \pm 18\%$). After the 8-week training program, both groups had mean insulin sensitivity values that were nearly similar (HI: 66 ± 27 versus LI: $74 \pm 42\%$), which may indicate a sort of natural 'regression towards a mean' effect for both groups. It may be hypothesized that arm exercise, where only a limited muscle mass can be used, may not be sufficient to elicit changes in glucose homeostasis. However, the role of exercise intensity in SCI individuals is not clear and needs to be restudied in further studies with larger groups.

All six subjects completed the 8-week arm exercise training period (92% participation of training sessions) and they were able to maintain the heart rate at the prescribed intensity of 40–50% HRR or 70–80% HRR. At present, relatively few studies have been conducted on the role of exercise intensity in patient groups. This is probably due to the fact that patients are usually unable to perform prolonged HI training and the greater risk of health complications and injuries. The interval training protocol as used in the present study enabled the patients to do substantial work at a relatively HI. Since the expansion of physical capacity and improvement of the lipid profile seems to be more pronounced in response to HI training, HI training seems to be preferable when the training is supervised and compatible with the fitness status of the patient.

Correlation study Eight out of 11 wheelchair-bound SCI subjects participating in the correlation study show a insulin sensitivity value below 100%, indicating a state of insulin resistance, in the early phase after the injury it self. In the present study, a significant correlation was found between insulin sensitivity (mean value $84 \pm 37\%$) and peak oxygen uptake (1.09 ± 0.35 l/min). This is in agreement with previous studies in able-bodied

populations where a highly positive correlation between insulin sensitivity and maximal oxygen consumption has been reported.^{15,16,31} The present results indicate that, as in the able-bodied population, peak aerobic capacity seem to be a predictor of insulin sensitivity in spinal cord-injured individuals. Metabolic disturbances such as a decreased insulin sensitivity are considered to play an important role in the increased risk for cardiovascular diseases in this group. Therefore, regular aerobic fitness assessment in SCI individuals may be of importance in the CVD prevention planning for the SCI.

Limitations of the study It is clear that the present study has several limitations that must be taken into consideration. First of all, the study was performed in fairly recently injured spinal cord-injured individuals in a primary rehabilitation setting where changes might be influenced by other factors like the usual rehabilitation program and natural processes of adaptations. Furthermore, no control group and only a small and heterogeneous group of subjects was included. They differed in sex, age, level and completeness of injury that all may have an effect on the results. However, we took post-test values relative to the initial values in order to overcome the large intersubject differences. Despite the evident limitations of the present study, it is of clinical relevance to find the most optimal treatment in SCI in the early rehabilitation phase itself. With early activation and mobilization, it might be able to avoid profound metabolic alterations, thereby decreasing cardiovascular risk factors and achieving optimal physical fitness that is desirable for functioning in daily life.

In conclusion, the use of an arm exercise interval training protocol as used in the present study enables recently injured SCI patients to do substantial work at a relatively HI. Improvements in physical capacity and lipid profile were more pronounced in response to high training intensity. A significant positive correlation was found between maximal oxygen consumption and insulin sensitivity, indicating that, as in the able-bodied population, the peak aerobic capacity is a predictive value with regard to insulin sensitivity in SCI. Further studies with larger groups assessing the effect of exercise on insulin sensitivity in the spinal cord population are recommended.

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