Original article

Arm cranking exercise improves carbohydrate and lipid metabolic disorders in sedentary adults with chronic spinal cord injury

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Abstract

Objective: To determine the influence of arm-cranking exercise (ACE) on improving disorders in sedentary adults with chronic spinal cord injury (SCI).

Methods: Seventeen male adults with complete SCI at or below the 5th thoracic level (T5) volunteered for this community-based supervised intervention. Participants were randomly allocated to the intervention (n=9) or control group (n=8) using a concealed method. The intervention consisted of a 12-week arm cranking exercise program, 3 sessions/week, consisting of warming up (10-15 min) followed by arm-cranking (20-30 min [increasing by two minutes and 30 seconds each in three weeks]) at a moderate work intensity of 50-65% of heart rate reserve (HRR), (starting at 50% and increasing 5% each three weeks) and by a cooling-down period (5-10 min). Plasma lipids profile was assessed using standard methods and techniques. Lastly, insulin resistance was evaluated by the homeostasis model of assessment insulin resistance index (HOMA-IR).

Results: After the completion of the training program, plasma lipid profile significantly improved. Similarly, insulin resistance was decreased. No changes were found in the control group.

Conclusion: A short-term, 12-week arm cranking exercise program improves carbohydrate and lipid metabolic disorders in adults with chronic SCI. [*Ethiop. J. Health Dev.* 2013;27(3):243-248]

Introduction

Accumulating evidence suggests that morbidity and mortality from cardiovascular diseases (CVD) are prevalent and occur earlier among individuals with chronic spinal cord injury (SCI) compared to those without such injury (1).

Among modifiable CVD risk factors, excessive body fat (2), dyslipidemia (3, 4), insulin resistance (HUANG) and hypertension (5) have been found to be prevalent in people with chronic SCI. This is consistent with recent findings reported by (in Swedish paraplegics, in which 57% had abnormal LDL-C and 43% had abnormal HDL-C (6). Furthermore, patients with paraplegia may have higher levels of serum total cholesterol and LDL-C than those with tetraplegia (7).

People with SCI showed sex-related differences in their lipoprotein profiles that indicated premenopausal women with SCI did not exhibit the adverse lipoprotein characteristics observed in men with SCI, probably because of the influence of sexual hormones independent of lesion level (8). Lastly, dyslipidaemia was found to be common at all body mass index categories in both men and women with chronic SCI (9).

Abnormalities of carbohydrate metabolism are also more common among people with SCI than in those without (10). In fact, there is a strong association between SCI and type 2 diabetes (11). More specifically, insulin resistance has been also identified as an important factor for the presence of carotid plaque by multiple linear regression analyses in male patients with traumatic SCI at thoracic level 6 or above (12). The resting energy expenditure of people with SCI is generally lower than that seen in healthy individuals, and carbohydrate is the predominant fuel source oxidized across a wide range of intensities during voluntary arm-crank ergometry in patients with SCI (13).

These findings should be useful for prioritizing preventive health strategies and planning long-term care for people with chronic SCI (3). In fact, a recent prospective cohort study showed that regular exercise has been associated with a lower mortality risk in adults with traumatic SCI (14).

Furthermore, training recommendations for people with SCI did not vary dramatically from advice directed to the normal population (15, 16).

In healthy individuals, exercise programs are important in the prevention and control of many metabolic syndrome-related disorders, particularly for carbohydrate and lipid metabolism disorders (17, 18). However, the available evidence does not support that findings from

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studies conducted on healthy individuals can be extrapolated to individuals with SCI (15). Furthermore, in a recent systematic review of the literature, evidence was still insufficient to determine whether exercise improves carbohydrate and lipid metabolism disorders among adults with SCI (16).

For the reasons mentioned, this study was conducted to determine the influence of a supervised arm-cranking exercise program on improving carbohydrate and lipid metabolic disorders in sedentary adults with chronic SCI.

Methods

Study Population:
A total of 17 male adults with complete SCI at or below the 5th thoracic level (T5) volunteered for this study from the community. The rationale of this sampling was that the work capacity of individuals with spinal cord injury at or above the 4th thoracic level (T4) is limited by reductions in cardiac output and circulation to the exercising musculature (19).

Injury level was determined from a motor and sensory physical examination using the International Standards for Neurological Classification of Spinal Injury written by the American Spinal Injury Association (ASIA) (20).

Inclusion criteria were defined as follows: men, aged 20-35 years, SCI at or below T5, all lesions traumatic, 4-5 years post-injury, medical approval for physical activity participation.

On the other hand, the exclusion criteria were: pressure ulcers and/or coexisting infections, toxic habits (smoking or alcohol), receiving medication that may interfere with metabolism, participation in a training program in the 6 months prior to participation in the trial, not completing at least 90% of the training sessions, a concurrent medical condition that might impact the ability to participate in an exercise program.

Intervention Program:
In the present randomized controlled trial, participants were randomly allocated to the intervention (n=9) or control group (n=8) using a concealed method. Characteristics of participants at baseline are summarized in Table 1. The control group consisted of individuals matched for age, sex and injury level. Control participants completed assessments, but did not take part in any training program.

Subjects assigned to the intervention group performed a 12-week arm-cranking exercise program of 3 sessions per week.

All participants underwent a pre-training period to be familiarized with the correct use of the arm crank ergometer. Each training session consisted of warming up (10-15 min) followed by the main part of the arm cranking exercise (20-30 min [increasing 2 minutes and 30 seconds each for three weeks]) at moderate work intensity of 50-65% of heart rate reserve (HRR) (starting at 50% and increasing 5% each for three weeks) and by a cooling-down period (5-10 min).

Heart rate reserve was obtained according to the following equation by Wilmore (21):

$$HRR = ((HRact - HRrest) \times (HR\ peak - HRrest)^{-1}) \times 100\%.$$

The resting heart rate (HRrest) was measured on one occasion during rest early in the morning before the training program started.

Exercise duration and intensity were carefully monitored in order to guarantee long-term compliance and injury avoidance (JACOBS). In this respect, participants wore a wireless heart rate monitor (Sport Tester PE3000, Polar Electro, Kempele, Finland). To perform each training session, they were placed on a chair that was connected to the arm-crank ergometer (Ergometrics 900 SH) with their legs and their hips fixed with belts for optimal stability. It should be pointed out that the pedal axis was aligned with the participant's shoulder, and participants were positioned such that their elbows were slightly flexed at maximal reach. Their feet were placed on the floor such that the knees were bent at an angle of approximately 90°.

Metabolic Measurements:
Blood samples were collected from the ante-cubital vein puncture after a 12 hours fast and collected by using an evacuated tube containing EDTA. The whole blood was centrifuged at 3000 rpm for 10 minutes in a clinical centrifuge. The plasma was separated and stored at -80º C until further analysis. Total cholesterol, high-density lipoprotein cholesterol (HDL-C), triglycerides and glucose were assessed according to guidelines (22). It should be pointed out that low-density lipoprotein cholesterol (LDL-C) was calculated using the Friedewald's formula (23). Finally, the ratio total cholesterol/HDL-C was also assessed.

Insulin resistance was evaluated by the homeostasis model assessment insulin resistance index (HOMA-IR) calculated as fasting plasma insulin (μU/ml) × fasting plasma glucose (mmol/l)/22.5 (24). Fasting plasma insulin concentration was determined using an insulin-specific immunoradiometric assay (IRMA).

All these outcomes at the individual level were assessed initially at baseline and at the end (72 h after the end) of the intervention program.

Ethics and Statistics:
This research has been conducted in full accordance with ethical principles, including the World Medical Association Declaration of Helsinki (version, 2002). Participants gave their written informed consent prior to

participation. Furthermore, the present protocol was approved by an Institutional Ethics Committee.

All data were analyzed using SPSS version 19 (SPSS Inc, Chicago, IL, USA). The results were expressed as a mean± standard error of the mean (SEM). The Shapiro-Wilk test was used to assess whether data were normally distributed. To compare the mean values, a one-way analysis of variance (ANOVA) with post-hoc Bonferroni correction to account for multiple tests was used. Pearson´s correlation coefficient (r) was used to determine potential associations among tested parameters. For all tests, statistical significance was set at an alpha level of 0.05. Finally, Cohen's d statistics were used for determining mean effect sizes. In this respect, the effect size was considered to be small: d ≥0.2 and < 0.5; medium d ≥ 0.5 and <0.8; large d ≥ 0.8, respectively.

Results

Plasma levels of total cholesterol (p=0.0082; d=0.90), LDL-C (p=0.0391; d=0.62), ratio TC/HDL-C (p=0.0412; d=0.46) triglycerides (p=0.0166; d=0.71) were significantly reduced after the completion of the training program. Conversely, HDL-C significantly changed in the intervention group (p=0.066; d=0.17). Plasma glucose concentration was significantly reduced (p=0.0403; d=0.65). Furthermore, insulin resistance was improved as HOMA-IR significantly declined after the completion of the intervention program: (p=0.0377; d=0.48). These results are given in Table 1.

Table 1: **Effects of arm-crank exercise on carbohydrate and lipid metabolism in sedentary adults with chronic spinal cord injury**.

	EXERCISING GROUP		CONTROL GROUP		
	Pre-test	**Post-test**	**Baseline**	**Final**	**Cohen´s d**
TC	4.7±1.1	4.1±0.9 [a,b]	4.9±1.2	5.0 ± 1.0	0.90
LDL-C	3.1± 0.7	2.7 ± 0.6 [a,b]	3.3 ± 0.9	3.2 ± 0.8	0.62
HDL-C	0.82±0.16	0.84±0.13	0.78±0.18	0.80±0.21	0.17
TC/HDL	4.7±1.2	4.1±1.0 [a,b]	4.9±1.4	5.0±1.3	0.46
TG	1.7±0.6	1.4±0.4 [a,b]	1.8±0.7	1.9±0.5	0.71
Glucose	5.6±1.5	4.9±1.2 [a,b]	5.8±1.7	6.0±1.7	0.65
HOMA-IR	1.56±0.72	1.28±0.64 [a,b]	1.61±0.60	1.63±0.58	0.48

Note: TC: Total cholesterol. TG: Triglycerides. Total/HDL-C: Total/HDL cholesterol ratio HOMA-IR: Homeostasis model assessment insulin resistance index. Results are expressed in mmol/l as mean ± sem. [a] p<0.05 versus pre-test; [b] p<0.05 versus control group (final).

No significant changes in any of the tested parameters were found in the control group. Finally, neither sports-related injuries nor withdrawals from the program were reported during the entire study period in the intervention group.

Discussion

The present study reveals that arm-cranking exercise improved serum lipid profile in adults with chronic SCI. Similar results were found in a homogeneous cohort of 5 men with neurologically complete spinal cord injuries at T6 to L1 that underwent 3 months of resistance training (25). In a similar experiment, it was found that an 8-week training program based on interval sessions at high intensity in recently injured adults with SCI decreased LDL-C and triglycerides concentrations as well as increasing HDL-C levels (26). Finally, a recent prospective cohort study concluded everyday physical activity seems to have an important role in improving lipid profile in patients with SCI (27).

These results could be explained, at least in part, given that participants trained at low/moderate intensity during the whole experience (50-65% HRR). Indeed, maximal fat oxidation during arm exercise in SCI occurs at exercise intensities below those of persons without SCI (28). Accordingly, increased participation in activities of daily living is associated with lower cholesterol levels in people with spinal cord injury (29, 30).

However, regardless of exercise intensity, people with SCI may not be able to oxidize high absolute or relative amounts of fat during voluntary exercise (30). This finding is supported by a report that fat oxidation rates in non-SCI individuals are lower during arm cranking exercise than with leg exercise at the same absolute percentage of VO2 peak (31).

Finally, the same intervention program reported in the current study showed reduced oxidative damage in adults with chronic SCI (32). These results are of particular interest given that oxidation of LDL-cholesterol plays a pivotal role in the pathophysiology of acute coronary syndromes (ACS) (33).

With regard to carbohydrate metabolism, arm-cranking exercise significantly reduced plasma glucose levels in the intervention group. Similarly, 12-week rowing exercise training has shown to have significantly decreased plasma glucose levels in male adults with chronic SCI (34). Consistent with these results, a second striking finding of the present study was that arm-cranking improved insulin resistance in the intervention group. In addition, a 12-week mixed protocol, based on both evoked resistance training and nutritional recommendations, resulted in significant improvements in insulin profile (35). In this respect, it should be emphasized that our protocol did not include dietary restriction so that it may be considered more feasible and practical for participants and relatives. On the other hand, home-based electrically induced resistance training for

16 weeks did not improve insulin resistance in adults with chronic SCI (36). The latter results may be explained, at least in part, given that participants underwent a home-based training program. Conversely, the current study consisted of a supervised arm cranking exercise program that ensured that participants underwent training sessions as well as the training workload of which was appropriate. Finally, physical exercise was also associated with lower insulin resistance in patients with lesion level between C5-C7 (37).

In spite of the fact that people with SCI face many obstacles to exercise (38), the current results provide strong arguments for strengthening the role of intervention programs based on regular exercises as a preventive strategy for this group. Promising results reported in the current study as well as in the literature (26, 34, 35) may finally provide scientific foundation to continue exercising after trials end.

Finally, the present study had some limitations that should be considered too. The small sample size may also limit the generalization of the results despite previous studies that have been published with the same (32, 39) and even smaller sample sizes (25, 26, 35, 36). Another weakness was the relatively short duration of the exercise intervention so that there was no follow-up to determine whether these positive effects induced by aerobic training were maintained.

On the other hand, strengths of this study included the homogeneous sample size in contrast to previous studies that enrolled males and females, tetra- and paraplegia, different etiologies for SCI, since injury and the like. In the same line, the presence of a control group consisting of age, sex and injury-level matched individuals may reduce the recruitment bias of healthy controls. Finally, the excellent adherence rate suggested, that the training program was effective and easy to follow-up. In fact, errors on the conservative side of selected exercise durations and intensities are prudent and even more important for persons training with a disability than those without (19). Overall, if it is taken into consideration that heavy work load injuries, joint dislocations and fractures have been reported as common in this group (40) and may ultimately compromise performance of essential daily activities, including wheelchair propulsion, weight loss and the like in this group (41). It should be also emphasized that no sport-related injuries were reported during the whole experience, which may indicate that not only the effectiveness but also the safety of the present arm cranking training for young adults with SCI.

It was concluded that a 12-week arm cranking exercise program may improve carbohydrate and lipid metabolism disorders in adults with chronic SCI. Future long-term investigations should extend these results by assessing whether correction of metabolic disorders improves clinical outcomes of individuals with SCI.

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