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Original Article

Proposal for a program of physical exercise for adults with spinal cord injury: effects on body composition

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Abstract
Problem statement: People with spinal cord injury have an increased risk for developing metabolic syndrome due to inherent changes in body composition caused by muscle atrophy below the level of injury, and the adoption of certain lifestyles, such as physical inactivity. Due to the barriers to access to gyms, exercise programs in the home environment itself can be an alternative to encourage people with SCI to a more active life. **Aim**: The aim of this study was to evaluate the influence of a physical exercise program, which can be performed at home, on the body composition of adults with spinal cord injury. **Methods**: Nineteen adults with spinal cord injury, aged between 18 and 58 years and sedentary, were allocated into two groups: control group (n= 9) and intervention group (n= 10). The IG participants were submitted to a 60 minutes session of physical exercise, twice a week, for 16 weeks. For the evaluation of the body composition, dual-energy x-ray absorptiometry was used before and after the intervention. Fat-free mass, total and local (arms, trunk, and legs) fat mass and relative android fat (%) were analyzed using a 2×2 repeated-measures ANOVA (group: intervention group *vs*. control group by moment: pre *vs*. post) ($P \leq 0.05$) and the effect size (Cohen's *d*) was calculated. **Results**: There were no major effects or significant interactions for the analyzed variables ($P > 0.05$). However, there was a small beneficial effect in favor of intervention group for the fat ($d = 0.43$) and lean ($d = 0.44$) masses of the arms and the android fat ($d = 0.32$). **Conclusion**: The physical exercise program for adults with spinal cord injury provided small positive responses in the body composition of the upper limbs and android fat, and it can be an interesting alternative for this population to practice at home.
Keywords: body composition; physical exercise; sedentary lifestyle; spinal cord injury; home exercises.

Introduction

Spinal cord injury (SCI) is a complex and irreversible condition that affects the functions of the motor, sensory, and autonomous system, interfering in psychic and social aspects of the individual's life and health status (Thietje & Hirschfeld, 2017). Due to the significant restrictions it imposes, SCI has both direct and indirect influences for the emergence of secondary conditions to health, which increase the risk of people with SCI developing chronic diseases with greater intensity and at younger ages, when compared to people without disabilities (van Diemen et al., 2017).

With the consequent atrophy of skeletal muscles and bone tissues in immobilized areas, which is caused especially by the motoneuron death and muscle denervation (Dionyssiotis et al., 2019), SCI can alter basal metabolism. This fact added to the low level of physical activity (PA), can lead to a considerable change in body composition. Overall, there is a decline in fat-free lean mass and an increase in the percentage of body fat, which is a primary contributor to the development of metabolic syndrome (Kirshblum & Donovan, 2017). Approximately six months after SCI, muscle fiber atrophy is observed together with an increase in intramuscular fat in the body as a whole, predisposing to reduced muscle resistance, premature hyperlipidemia, and glucose intolerance (Pelletier et al., 2016). On average, this population presents 5kg more fat mass and 50% more total body fat when compared to those without disabilities (Galea, 2012).

Another problem is that most people with SCI have a sedentary lifestyle (Devillard et al., 2007; Nooijen et al., 2012). When comparing their level of PA with individuals without disabilities, it is much lower, even lower than the PA levels of people with other types of disabilities (de Hollander & Proper, 2018), a habit considered as an aggravating factor for health and autonomy. In Brazil, for example, only 14% of those with physical disabilities are physically active, compared to 54% of people without disabilities (Greguol, 2017).

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The health benefits of regular PA are irrefutable, representing an effective preventive measure against more than 25 chronic health conditions, as well as premature mortality (Warburton & Bredin, 2016). Several studies have confirmed the effects of physical exercise on different health and physical fitness variables, without any harm to the health of people with SCI (Alves et al., 2020; Fidler et al., 2017; Nightingale et al., 2017). General recommendations for the practice of PA have been produced, using the voluntary action of the active muscles above the level of the injury (Martin Ginis et al., 2018; Tweedy et al., 2017). However, there is still no consistency and understanding of the most appropriate physical exercise program to maintain or improve the body composition of people with SCI (Tweedy et al., 2017; van der Scheer et al., 2017).

Most of these studies also were proposed in specific commercial equipment for wheelchairs and in their environments, such as gyms, which are not viable for the economic reality of many people with disabilities. Therefore, more economically accessible initiatives that can be carried out in the domestic environment can be interesting alternatives in developing countries, such as Brazil, which has little participation of people with disabilities (Greguol, 2017). Given the relevance of this topic and the growing search for accessible physical exercise alternatives for people with SCI, the objective of the present study was to evaluate the interference of a physical exercise program (PEP), which can be practiced at home, in the body composition of adults with SCI. We hypothesized that the PEP promotes improvements in body composition. Besides, this investigation may assist different therapeutics, physicians, and other health professionals to improve their interventions and treatments for this portion of the population.

Methods

Participants

Nineteen men with paraplegia participated in the study. As inclusion criteria, participants were required to be male, over 18 years of age, have been diagnosed with SCI for at least one year, and use only a wheelchair for mobility. As exclusion criteria, they were required not to be considered physically active, and not to use medications and/or diet for weight loss, or have pressure ulcers, urinary tract infections, pulmonary, osteoarticular shoulder, or cardiovascular complications that limit the practice of physical exercises.

Participants were recruited from hospitals specializing in the care of trauma patients and physical therapy clinics. The composition of the groups occurred based on the availability of transportation and/or an accompanying person to travel to the training location. Those who remained in the control group (CG) received follow-up throughout the study period to obtain information about their health status, or about changes in some lifestyle habits. The CG was formed by nine participants, and the intervention group (IG) by 10 participants. The sample size (G*Power 3.1.9, Franz Faul, Germany) was estimated for a minimum of 16 participants needed to detect an average difference of 5% in body composition for the IG, considering a power of 80% ($\beta = 0.20$) and a single-tailed significance level (α) of 0.05. The level of habitual PA was determined using the Brazilian short version of the International Physical Activity Questionnaire (IPAQ), with adaptations to the reality of people with SCI, especially concerning mobility in a wheelchair. The diagnosis of the level and severity of SCI was performed by a neurologist according to the American classification of SCI (ASIA). Socioeconomic information and related to rehabilitation and health status were obtained by a semi-structured interview. This study was approved by the local Human Research Ethics Committee (Opinion number 1.371.194/2015), and all participants signed an informed consent form.

Anthropometry and Body composition

Body mass and length were measured and the body mass index (BMI) was calculated. Dual-energy x-ray absorptiometry (DXA) was used to analyze body composition by the Lunar Prodigy Advance device (GE Lunar, USA). The technique involves passing a beam of double energy radiation through the subject, who remains positioned in the supine position, on the scanner table. The diagnosis of obesity for people with SCI was determined by the BMI> $22kg/m^2$ (Laughton et al., 2009) and the percentage of total fat mass (%FM≥ 25%) (Cruz-Jentoft et al., 2010). The sarcopenia was set as the appendicular lean mass index (ALMI), which corresponds to relative fat-free mass (FFM) (arms and legs)/length^2, with values ≤$7.26kg/m^2$ (Cruz-Jentoft et al., 2010). The measures chosen for the analysis included absolute and FFM, total and relative regional FM (arms, trunk, legs), and android fat (AF).

Intervention

For the PEP, combined training (aerobic + resistance) was chosen. Aerobic training was performed on a wheelchair-specific ergometer (Souto, 2018), and resistance training employed elastic bands with different types of tension. The choice for both types of equipment was due to the low cost compared to other commercial equipment and the fact that it allows the user to perform the exercises in the wheelchair itself and at home.

The PEP was performed for 16 weeks, with two weekly sessions and an approximate duration of 60 minutes per session. In each session, joint warm-up and stretching for 5 minutes were performed, followed by 20 minutes of continuous moderate-intensity aerobic training, at 50 to 70% of heart rate (HR) reserve, on a wheelchair ergometer. This training effort intensity was determined from the modified multistage incremental field test in the form of MFT-8, proposed by Weissland et al. (2015). An HR monitor was used to monitor the intensity of aerobic training (FT10, Polar, Finland).

For participants with injuries equal to or higher than the T6 level with possible changes in the autonomous system, care was taken to monitor the training and to avoid possible discomfort. To avoid autonomic dysreflexia, there was guidance for bladder and bowel relief before exercise/testing. As for avoiding thermal dysfunction, it attempted to maintain at room temperature. For the control of the intensity of the aerobic training, for those who presented a decrease in the response of the sympathetic nervous system to the effort, and consequently a reduction in the maximum HR compared to people without disabilities (Perret & Abel, 2016), the Borg scale of subjective perception of effort was applied. Subsequently, muscular resistance training was performed for the large muscle groups of the upper limbs and trunk. With the use of rubber bands, three sets of 12 repetitions of the following exercises were performed: lat pull down, bench press, close row, pec flies, Arnold press, biceps curl, and lying triceps extensions. The progression of the load in the resistance training was spontaneous, being increased as the individual managed to perform the three series with 12 complete repetitions, through increases in the tension and/or the number of elastics, with the help of the physical education teacher who followed each participant. At the end of the session, stretching exercises were performed on the muscle groups involved in the training.

Statistical analysis

Normally distributed data (Shapiro-Wilk test) were reported by mean and standard deviation, otherwise by median and interquartile range. Categorical variables are presented as absolute (n) and relative (%) frequency for some variables and, when relevant, the groups were compared using the Chi-square test. Age, age at SCI acquisition, and SCI time were compared between groups using the Mann-Whitney U test. The repeated-measures ANOVA was used to analyze significant changes depending on the group (IG *vs*. CG) and moment (pre *vs*. post). If a significant effect ($P< 0.05$) was found for the group × moment interaction, paired comparisons *versus* the CG were performed by the Bonferroni's post hoc. Additionally, the effect size (Cohen's d) with a 90% confidence interval (90%CI) was estimated and interpreted as follows: $d< 0.20$ trivial, $d= 0.20$-0.59 small, $d=$ 0.60-1,19 moderate, $d= 1.20$-2.00 large and $d> 2.00$ very large. The data were tabulated and analyzed using the IBM Statistical Package for the Social Sciences, version 25.0 (IBM Corp., Armonk, USA).

Results

Most members of the study reported having participated in rehabilitation programs previously and sought support in the primary health care network for direct and indirect complications related to SCI. Most of the participants were married, with children, in lower social classes, with income from disability retirement. At the beginning of the study, no differences were found between the groups in general characteristics related to age, characteristics of SCI, and time of injury ($P> 0.05$). The neurological category and etiology of SCI in both groups remained similar and were grouped according to the recommendations of DeVivo et al. (2011) (Table 1). Likewise, in each group, four participants had an injury equal to or higher than the T6 level. The only individual affected by congenital causes did not present scoliosis or respiratory changes that limited his participation in the study.

Table 1 Characteristics of study participants.

Variable	Group	
	Control (n= 10)	Intervention (n= 9)
Age (years)	30 [10.0]	37 [6.7]
Age at the acquisition of SCI	23 [7.2]	25.4 [11.8]
Injury time (years) Md	6.5 [15]	8 [22]
Neurologic Category	T1-S5 ASIA A: 8 T1-S5 ASIA B: 1 T1-S5 ASIA D: 1	T1-S5 ASIA A: 7 T1-S5 ASIA B: 1 T1-S5 ASIA C: 1
Etiology	Traumatic: 9 Non-traumatic: 1	Traumatic: 6 Non-traumatic: 3

Numerical variables are presented as mean and standard deviation or median (Md) and interquartile range. Categorical variables are expressed as absolute frequency.

Regarding the initial changes in body composition, 10 of the participants (52.6%) were classified as obese (three from the CG and seven from the IG, BMI> 25kg/m^2). In the analysis of obesity by %FM≥ 25%, two more individuals, one from each group, totaling 12 (63.1%), were also categorized as obese. Sarcopenia was identified in 18 participants (94.7%), remaining absent in only one individual with obesity due to the %FM≥ 25% of the IG, based on the ALMI≤ 7.26kg/m^2. The body length at the pre-intervention moment was higher in the GC [1.72 (0.7) m] compared with IG, [1.62 (0.1) m], ($P= 0.022$). Thus, the variables FFM, total and regional FM, and AF were normalized through the use of reported data only in percentage (%).

Table 2 summarizes the effects of the PEP for men with SCI. There were no major effects or significant interactions for the analyzed variables ($P> 0.05$). However, there was a small positive effect in favor of IG for decreasing fat mass ($d= 0.43$) and increasing lean mass ($d= 0.44$) of the arms and decreasing android fat ($d= 0.32$).

The other effects were null or trivial for the total body composition (d< 0.18) and segmented for the trunk (d< 0.069) and legs (d< 0.114). Changes in the arm segment were insufficient to reduce the frequency of IG obesity or sarcopenia.

Table 2 Body composition of people with SCI by group at pre- and post-intervention moments.

Variable	Group	Moment Pre	Post	Δ	Cohen's *d* [90%CI]
Total Mass					
Total fat mass, %	Control	21.7 (13.9)	22.1 (14.5)	0.4	0.188
	Intervention	30.9 (5.5)	29.9 (6.1)	−1.1	[−0.57; 0.94]
Total lean fat mass, %	Control	73.9 (13.6)	73.5 (14.1)	−0.3	0.121
	Intervention	65.3 (5.3)	66.3 (5.9)	1.0	[−0.63; 0.88]
Arms					
Fat mass arms, %	Control	11.1 (7.9)	12.7 (9.3)	1.6	0.431
	Intervention	17.4 (5.8)	15.9 (5.8)	−1.5	[−0.34; 1.19]
Lean mass fat arms, %	Control	83.4 (7.4)	82.0 (8.5)	−1.4	0.441
	Intervention	78.0 (5.2)	79.3 (5.5)	1,3	[−0.32; 1.20]
Trunk					
Fat mass trunk, %	Control	22.8 (15.3)	23.1 (15.9)	0.3	0.069
	Intervention	33.2 (6.9)	32.6 (6.7)	−0.6	[−0.69; 0.82]
Lean mass fat trunk, %	Control	74.4 (15.6)	73.8 (16.1)	−0.6	0.080
	Intervention	64.3 (6.8)	64.7 (6.5)	0.4	[−0.75; 0.76]
Legs					
Fat mass leg, %	Control	28.0 (16.8)	28.1 (17.4)	0.1	0.114
	Intervention	37.7 (7.9)	36.3 (8.4)	−1.4	[−0.64; 0.87]
Lean mass fat leg, %	Control	67.4 (16.7)	67.4 (17.7)	0.0	0.102
	Intervention	58.4 (7.4)	59.8 (8.0)	1.4	[−0.65; 0.85]
Android Fat					
Android Fat, %	Control	25.3 (17.5)	25.1 (17.1)	−0.2	0.319
	Intervention	38.6 (9.4)	33.9 (13.7)	−4.7	[−0.46; 1.10]

Data presented as mean (SD). Δ= Post − Pre. d, effect size, with 90% confidence interval (90%CI).

Discussion

This study evaluated the interference of a PEP for adults with SCI on body composition. Our hypothesis that the PEP promotes improvements in body composition was accepted partially. Considering that changes in FM and LM are capable of impairing functional independence, energy expenditure, and insulin resistance (Gater Jr, 2007), monitoring changes in body composition over time, as well as possible impacts of interventions from physical exercise programs on body composition, is very important due to its social and health implications for the SCI population.

These physical exercise programs must seek alternatives to overcome barriers that limit the participation of people with SCI and expand their access. Some researchers have proposed the use of the upper limbs, with different equipment in the residence itself (Bass et al., 2020; Sasso & Backus, 2013; Valent et al., 2009). However, the analysis of responses to training in these studies did not include body composition. Our proposal was structured to reach a larger number of subjects since the lack of transportation and specific programs are one of the main perceived barriers to the practice of physical exercises by people with motor disabilities (Seron et al., 2015; Vasudevan et al., 2015). Thus, together with the economic reality of the population with disabilities, low-cost equipment was sought, as well as the possibility of carrying out PA at home.

When analyzing the initial status of the research participants, it was possible to identify a significant presence of sarcopenia (94.7%) and obesity (63.1%) by the %FM≥ 25%. An expressive prevalence was also observed in a previous study with 136 adults of both sexes with SCI, 57% of whom were classified as having sarcopenia and 72% with obesity (Galea, 2012). These data are also reinforced by the study of Dionyssiotis et al. (2019) who compared men of the same age, with and without spinal cord injury, and found 97% of sarcopenia cases in the first group, against 41.9% in the second group.

Concerning the PEP response in body composition, our study identified an inconsistent improvement after 16 weeks of training, with a small positive effect on the fat and lean mass of the upper limbs and AF. On the other hand, those who did not participate in the program, after 16 weeks, exhibited higher values of FM and reduced LM. These results suggest that the PEP generated better results in the most used body area during training. In another study by de Zepetnek et al. (2015) with a similar training program for individuals with SCI, the results showed maintenance of body composition in the experimental group, especially in the total FM (kg), without interference in the total LM (kg). According to Nightingale et al. (2017), it is important to consider that it is extremely difficult with movements restricted only to the skeletal muscles of the upper body to generate an energy deficit capable of inducing a reduction in adiposity.

Despite this, Fisher et al. (2015) highlight that the duration, level, and severity of the SCI are directly related to body composition. The heterogeneity of the SCI levels, added to other intervening factors, such as the lack of measurement and control over diet, could limit the analysis of the results. However, the reduced training volume (40 minutes of aerobic training + resistance training) may have influenced this modest improvement, despite being higher than those who remained in the CG. According to Martin Ginis et al. (2018), after a recent review of the Canadian proposal for a specific guideline for people with SCI, it was suggested that the minimum dose needed to improve cardiometabolic variables, such as body composition, consists of a 30-minute aerobic exercise session, at moderate to vigorous intensity, 3 times a week. However, the recommendations of Tweedy et al. (2017) suggest that people with SCI should combine aerobic exercise (≥30 min at moderate intensity, 5 times a week or ≥20 min at vigorous-intensity, 3 times a week), with resistance training and flexibility twice a week.

An exclusively aerobic exercise program was performed using a hand crank ergometer for 30 minutes, 3 times a week, for 10 weeks, at 70% of VO2peak in 10 adults, 30% of whom were classified as quadriplegic and 70% as high paraplegia. The authors did not observe any improvement in the total and segmental composition (upper and lower limbs and trunk) (Bresnahan et al., 2019), although this protocol followed the minimum recommendations proposed by Martin Ginis et al. (2018) about cardiometabolic benefits. This outcome raises the hypothesis that the combination of aerobic exercise, even with lower volume, and resistance exercise, may have led to better responses in the segmental body composition of the upper limbs in the IG in the present study.

The qualitative inference for %FM and %LM of the upper limbs, although small, demonstrates that these measures were potentiated by the PEP performed in men with paraplegia. Although an increase in lean mass cannot predict an increase in strength, these factors are significantly correlated, and will probably contribute to the autonomy of people with SCI to perform activities of daily living. It is important to highlight that in addition to the maintenance and improvement of metabolic variables, physical exercise programs should be concerned with expanding the potentialities of practitioners in the execution of physical tasks, using mainly their upper limbs.

Despite the small qualitative interference of AF after PEP was not sufficient to change the obesity profile of IG participants, it indicates possible interference from exercise for central adiposity. Tanhoffer et al. (2014), when comparing men with SCI engaged in physical activity for at least 150 minutes a week (n= 6) with their inactive peers (n= 7) using the bioimpedance analysis method, identified significantly better results in the first group for the %FFM, although they were still considered obese. Likewise, Inukai et al. (2006), when analyzing the total and segmental distribution of fat mass by DXA in 25 Japanese athletes with SCI, reported the weekly training volume (seven hours or more) as the biggest influence in the reduction of the percentage of total and segmented fat.

In the current study, there were concerns over the participants' lack of previous experience with the practice of PA in the condition with SCI and the availability of time to adhere to the intervention program. For this reason, a lower volume of aerobic exercise was offered, which could be well tolerated by individuals without a greater risk of injury or withdrawal. Despite the small volume of weekly physical exercise applied in our research compared to previous studies, some results indicated slight positive changes for the IG in visceral fat. Among the alternatives for physical exercise interventions, it is important to note that the use of voluntary action of the upper limbs is the most accessible for the majority of the population with SCI, due to the high cost of other programs such as electrostimulation or gait training with reduced body weight, a fact that corroborates the need for research in the area.

As limitations of the present study, we mention the reduced sample size and the fact that the participants were selected for convenience. Finally, the weekly frequency of the intervention and the option of using elastic bands instead of free weights for resistance exercise may have limited the appropriate increase in the intensity of the effort. Despite this, it is believed that this research contributes to the understanding of the effects of an exercise program on body composition in SCI. Besides, the adopted program has wide practical applicability, as it uses low-cost equipment and can be applied in a home or hospital environment.

Conclusion

The PEP for adults with SCI provided small positive responses in the body composition of the upper limbs and android fat. It is noteworthy that the physical exercises prescribed are simple to adapt to the home environment, which can be an interesting alternative for individuals with SCI who often do not have access to existing programs in gyms or other PA centers. More precise adjustments in the progression of training intensity, in addition to a greater number of participants that allow stratification of results by injury level, may offer more adequate information to dimension the initial basis of a physical exercise program aimed at people with SCI.

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