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RESEARCH

Effects of high-intensity and progressive volume resistance training on functional, mental states, and quality of life of people with spinal cord injury

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Abstract

Objective To establish the effect of high-intensity and progressive volume resistance training (HIRT), on general health, functional, mental status, and quality of life (QOL) indicators in people with spinal cord injury (SCI).

Methods The sample consisted of five people with SCI of both sexes, aged 46.2 ± 13.9 years, submitted to 12 weeks of HIRT, twice a week. We analyzed before and after the 12 weeks of intervention: body composition, muscle strength, functional status, perception of mental status, and QOL, using the following tests: dual-energy X-ray densitometry, 1RM, isometry of biceps, elbow flexion, Wingate, zigzag, medicine ball pitch, Beck inventory (anxiety, depression, and mental disorder) and SF-36.

Results The results pointed to an increase in the training load, the total bone mineral content ($p=0.043$), the muscle power at 80% of 1RM ($p=0.043$), the functional state (anaerobic power [MD = 6.81%; $p=0.043$] and explosive strength [mean difference (MD) = 30.57%; $p=0.043$] of the shoulder girdle muscles), the mental state (MD = 71.46%; $p=0.006$) and finally, improvement in QOL, especially in the functional (MD = 60.87%; $p=0.006$) and social aspects (MD = 44.44%; $p=0.006$).

Conclusions HIRT can improve or maintain body composition, developing muscle power, anaerobic power, and explosive strength of the upper limbs that will impact functional capacity, promoting greater autonomy, with consequent reflex in improving mental state and of the QOL of the person with SCI.

Keywords Spinal cord injury · Muscle power · General health · Resistance training program · Mental health · Functional capacity

Introduction

Physical training has been used as a tool to improve functional, cardiorespiratory, psychological, and quality of life (QOL) aspects of adults with spine cord injury (SCI) [1]. One of the possibilities of physical training is resistance training (RT), widely used for health benefits, such as decreased insulin resistance, improved musculoskeletal system, prevention of osteoporosis and sarcopenia, contributing to the maintenance of functionality, increased resting metabolic rate, blood pressure control, improvements in body composition, reduced risk for heart disease and various types of cancer [2].

RT has been indicated in the guidelines for exercise prescription for people with SCI, as it is a type of physical exercise that improves neuromuscular, cardiometabolic, and functional components [1, 3]. In addition, there is a prior and consistent number of evidence regarding the administration of physical exercise for patients with SCI [3], so this type of exercise also seems to induce improvements in general physical health, mental health, and QOL, being, therefore, a possible strategy to be used to promote these physical and mental health benefits in people with SCI [3]. It is well described in the study of Pebdani et al. [4] that through a qualitative approach interviewed 16 SCI individuals and noted that the patients related that the prior experiences with

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physical exercise were able to improve their independence in performing activities of daily living (ADLs) and better engagement in the society, thus, providing benefits for the quality of life of these patients [4].

Considering the increase in life expectancy of people with SCI [5], understanding the possible effects of RT on indicators of physical and mental health, functional capacity, and QOL of these specific group of patients in a single intervention can help establish a non-drug intervention strategy to promote and maintain health, improve functional independence and QOL for these individuals during the whole course of their lives. Another benefit worth mentioning is the possibility of proposing a more complete assessment of the individual with SCI, considering several factors that constitute it, and avoiding a segmented assessment proposal [3].

Recent evidence attests not only to the benefits of resistance training but also recommends the progression of the training load. Recent positions establish that individuals with SCI should train between 30 and 60 min, twice a week with at least three sets for each exercise at moderate to high intensity. In addition, training volume and load progression are important to obtain long-term benefits from RT [3]. In a prior meta-analysis, Santos et al. [6] found a significant and positive effect of RT on the muscle strength of SCI patients without presenting side effects; nonetheless, these initial effects were obtained from only five articles, thus showing the importance of the production of more trials investigating RT approaches with SCI patients [6].

Thus, this work seems to be the first to propose evaluations of muscular strength, anaerobic power, functionality, and aspects of physical and mental health in a single study seeking to understand the individual in a global profile, and considering that, there are few studies about the effects of high-intensity resistance training (HIRT) and progressive workload to improve the QOL in people with physical limitations and with contradictory results [7, 8]. Thus, this work aimed to verify the effect of a HIRT program, with a progressive volume, on general health, functional, mental status, and QOL indicators in people with SCI.

Methods

It was a single-arm trail, with measurements performed in two distinct moments (pre- and post-test). All study procedures were developed at the Strength Laboratory of the Physical Education Department of the Federal University of Viçosa (UFV), city of Viçosa, Minas Gerais state, Brazil. The participants consisted of five people with SCI in a chronic phase with a mean age of 46.2 ± 13.9 years, 60% of whom were women ($n = 3$). The lesions of all study participants were located in the thoracic region. The causes of injuries were diverse, and the average injury time was 19.6 ± 17.0 years. All participants started the study with 1 year of previous experience in resistance training. The inclusion criteria were: (A) Having an SCI at the thoracic level; (B) Being physically able to participate in the experimental study, confirmed by a medical examination; (C) Having a sufficient degree of independence in the performance of the ADLs; (D) Not having musculoskeletal or cardiometabolic problems that limited or contraindicated the practice of programmed exercise; (G) Subject who did not participate in other regular exercise programs; (H) participation in more than 80% of the proposed training sessions. All subjects participated voluntarily, signed the Free and Informed Consent Form, and received information about the study, as determined by Resolution 466/2012 of the National Health Council. The study was approved by the research ethics committee involving human beings at the Federal University of Viçosa, Minas Gerais, Brazil, and was conducted under the license number CAAE: 51624715.2.0000.5153.

Control of the level of physical activity

Since the present study did not include a control group, to ensure that the effects obtained in the study were due to the intervention, control of the level of physical activity of the participants was carried out through the adapted International Physical Activity Questionnaire (IPAQ) [9], because this is a possible confounding variable that needed to be controlled to analyze the results. The IPAQ has been modified [10] to include activities appropriate for wheelchair users: wheelchair activities that represented vigorous intensity (e.g., wheelchair running, moving on unpaved terrain, wheelchair basketball, strong or fast pedaling) and moderate intensity (for example, turning or pushing for pleasure, using a cycle ergometer sparingly, pedaling at a regular pace) physical activity based on other measures of specific SCI physical activity. As for the walking, the respondents were asked to touch the chair lightly.

Depression

For depression measurement, the Beck's Depression Inventory [11] was previously validated for the Brazilian population by [12]. This scale consists of 21 questions about the occurrence of depressive symptoms in the last 15 days. The question's punctuation ranges in in an ordinal scale of 0–3, with the total scale ranging from 0 to 63 points. The thresholds for depression are considered as described: 0–13, minimal/no depression; 14–19, mild depression; 20–28, moderate depression; and 29–63, severe depression. The same evaluator made all the evaluations.

Anxiety inventory

Anxiety feelings were measured with the Beck's Anxiety Inventory [13], also validated for the Brazilian population by Cunha et al. [14]. This questionnaire contains 21 questions with answer options ranging from 0 to 4 on a Likert scale. The punctuation ranges from 0 to 63 points, were: score 0–21, low anxiety, 22–35, moderate anxiety, ≤ 36, potentially and concerning levels of anxiety.

Mental disorder

The mental disorder risk was measured with the usage of the Sel-reported questionnaire (20-item version, by Climent & Plutchick) [15] and validated for the Brazilian population by Mari & Williams [16]. This tool consists of a 20-item questionnaire with a dichotomic class of answers (yes = 1, no = 0), which measures feelings that are related to mental suffering and helps to indicate the risk of clinical mental disorders. For this purpose, the questionnaire has its questions divided into four categories as follows: depressive-anxious mood, somatic symptoms, decrease in vital energy, and depressive thoughts.

Quality of life

The participant´s quality of life was measured with the application of the questionnaire self-reported questionnaire of 36 points (SF-36) [17], in its validated form to Brazilian patients Ciconelli et al. [18] is a 36-item questionnaire, which measures dimensions such as functional capacity, limitation physical aspects, ache, vitality, social aspects, and mental health.

Body composition

The assessment of body composition utilized the dual X-ray absorptiometry (DEXA) method, and the Lunar Prodigy Advance DXA System device (version 13.31) from GE Medical, model 8743, located in Madison, WI, USA, was employed. This system measured bone mineral density (BMD) and bone mineral content (BMC) in the lumbar spine (L1–L4) and femoral neck, as well as segmentation data from total body mass (BM), total fat mass (FM) and total lean mass (LM) from the participant's arms [19].

Training protocol

The intervention of the present study was designed according to the guidelines for physical exercise for people with SCI [3] and the guidelines of the American College of Sports Medicine for RT [20]. The volunteers were submitted to 12 weeks of RT. The interventions took place twice a week, with an average duration of 60 min, in which the volunteers performed 8 exercises for the functional muscle groups, performing 3–4 sets of 8–12 repetitions for each exercise, with a 1-min rest interval between sets. The training was designed with the execution of all exercises in the wheelchair itself, seeking the execution with the least possible adaptation, consisting of eight exercises: rowing at the cross; dumbbell lateral rises; dumbbell biceps curls; triceps rope on the cross (volunteers from coast to device); supination handle thread; pronation handle thread; Shoulder press on the guided bar and horizontal adduction with dumbbells. The periodization of the HIRT program followed the schedule represented in Table 1.

Statistical analysis

The Shapiro–Wilk test was used to calculate the distribution of the data. In sequence, in the case, the data were presented in a parametric distribution, the dependent t test was used to calculate the statistical differences between means in the pre- and post-test. When the data were presented in a non-normal distribution, the Wilcoxon test was applied. The level of confidence of 95% ($p < 0.05$) was considered as the target threshold for statistical significance [21]. The Cohen's d effect size [22] was calculated for the mean differences between the pre- and post-test to identify the clinical relevance of the findings. For this purpose, the effect size cut-offs of ($\leq 0.1 = \text{small}, \geq 0.3 = \text{moderate}, \text{ and} \geq 0.5 = \text{large}$) were considered to evaluate the meaningfulness of statistical changes [22]. The statistical power was calculated based on a high effect size (≥ 0.5) and a two-sided Gaussian hypothesis, within a confidence interval of 95% ($p < 0.05$). The

Table 1 Periodization of the resistance training program over the 12 weeks of intervention

Training weeks											
1–2		3–4		5–6		7–8		9–10		11–12	
Sets	Rep	Sets	Rep	Sets	Rep	Sets	Rep	Sets	Rep	Sets	Rep
2	8	3	8	3	10	3	12	4	10	4	12

Rep Number of repetitions

Statistical Package for Social Sciences (SPSS, version 21.0) was used to perform all the statistical procedures.

Results

There were no changes in the participant's physical activity levels from the pre- to post-test (Pre = 982 ± 1308.82 min; Post = 1444 ± 1055.63 min; $p = 0.22$; $d = 0.35$). There was no injury record during the 12 weeks of intervention, related or not to the intervention. In addition, all participants completed the 12-week intervention. Figure 1 shows the control of the total training load for a period of 12 weeks. It is possible to observe a statistically significant evolution in the total training load, over the 12 weeks of intervention, in which differences were found between the first and the sixth week of intervention ($p = 0.05$), between the sixth to the twelfth week ($p = 0.02$) and an improvement in the entire intervention between the first and the twelfth week ($p = 0.001$).Note: Control of the total training load during the 12 weeks of intervention. *statistically significant improvement compared to the first week, #statistical improvement comparing with the twelfth week of RT.

Table 2 shows the results regarding body composition, total and segmental, and the bone mineral loss index throughout life (T-score). There was an increase in total LM, in the total bone mineral content (BMC), and in the total BMD of femur.

Table 3 presents the results of the assessment of muscle strength subdivided into maximum isometric strength, maximum dynamic strength, and muscle power, as well as the functional state represented by the agility tests, anaerobic power, and explosive strength of the scapular girdle muscles. There was an increase in muscle power with higher loads (80% RM), in the peak of muscle power (PP), in the maximal anaerobic power (MAP), in anaerobic power (AP) in the absolute anaerobic power (AAP), in the relative average anaerobic power (RAAP), and in the explosive strength of the scapular girdle muscles (ESSWM) with the maintenance of agility.

Table 4 shows the impacts on mental status: anxiety, depression, and mental suffering, and on QOL indicators. There were significant reductions in the anxiety symptomatology factor, as well as in the symptoms of depression and mental disorder. Therefore, there were also improvements in the participant´s functional capacity perception and the QOL social aspects dimensions.

Discussion

This study aimed to establish the effect of an RT program on indicators of general health, functional and mental status, and QOL in people with SCI. The main results obtained were: (1) The intervention with RT induced increases in the total training load, even the intensity between7 and 9 on OMNI-RES Scale, throughout the 12 weeks; (2) The RT promoted an increase in the total BMC and maintenance of the body composition of people with SCI when analyzing the body regions, mainly of the spine and arms; (3) The RT

Fig. 1 Control of the total training load

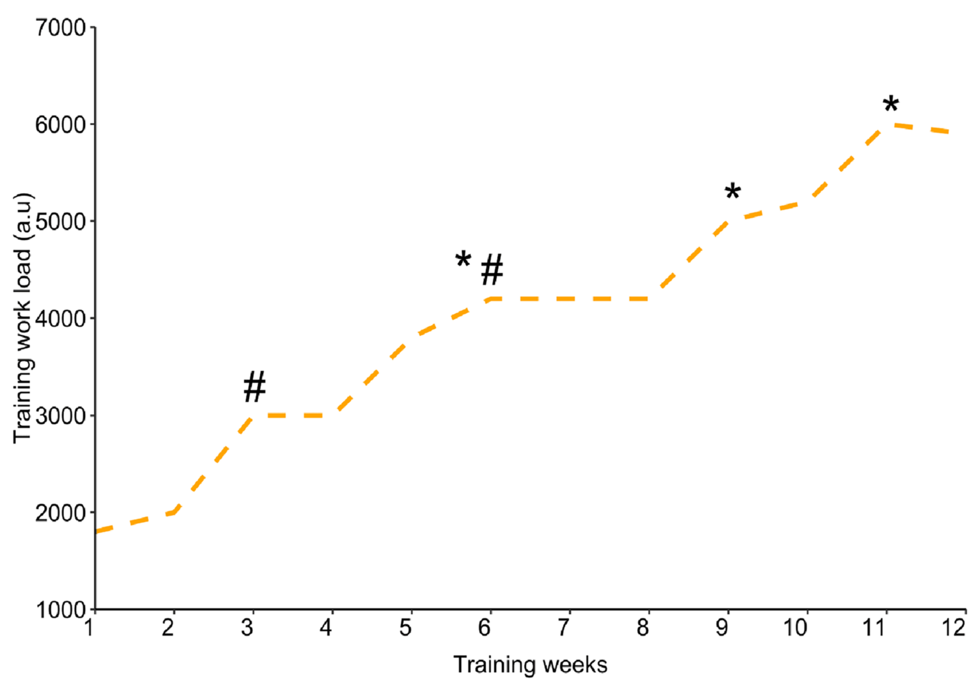

Table 2 Comparison of muscle strength, anaerobic power, and functional capacity values between the moments before and after 12 weeks of resistance training

Variables	Pre		Post		*p* value	ES
	Mean	SD	Mean	SD		
BM total	58.26	10.34	58.84	11.04	0.273	0.06
FM total (kg)	20.99	4.47	22.47	4.90	0.080	0.33
LM total (kg)	34.23	7.31	35.20	6.99	0.043*	0.14
BMC total (kg)	20.84	5.06	21.20	5.03	0.043*	0.07
T-score total	− 1.28	1.10	− 1.64	1.13	0.068	0.33
BM arms (kg)	6.70	1.40	7.30	1.50	0.420	0.43
FM arms (kg)	1.41	0.28	1.66	0.38	0.430	0.25
LM arms (kg)	5.00	1.24	5.31	1.29	0.430	0.25
BMC arms (kg)	0.31	0.06	0.32	0.07	0.080	0.17
BMC femur (g)	18.21	6.79	19.91	5.94	0.043*	0.29
BMD femur (g/cm)	0.672	0.119	0.670	0.123	0.715	0.02
T-score Femur	− 2.80	0.91	− 2.78	1.00	0.713	0.02
BMC spine (g)	53.66	10.42	56.39	12.09	0.080	0.26
BMD spine (g/cm)	1.11	0.13	1.11	0.13	0.680	0.00
T-score Spine)	− 0.84	1.08	− 0.78	1.14	0.680	0.06

**p* 0.05 (Wilcoxon), b medium effect size, c small effect size, *SD* standard deviation, *ES* effect size, *BM* Body mass, *FM* Fat mass, *LM* Lean mass, *BMC* Bone mineral content, *BMD* Bone mineral density, T-score Lifetime bone mineral loss

Table 3 Comparison of muscle strength, anaerobic power, and functional capacity values between the moments before and after 12 weeks of resistance training

	Pre		Post		*p* value	ES
	Mean	SD	Mean	SD		
MIVC (kg)	14.74	6.32	15.96	5.24	0.138	0.19
RM (kg)	21.60	9.84	22.40	8.56	0.357	0.08
MP40 (watts)	35.23	22.93	40.15	18.35	0.138	0.21
PP40 (watts)	72.54	53.94	75.22	43.04	0.500	0.05
MP60 (watts)	39.91	24.04	50.91	24.97	0.080	0.46
PP60 (watts)	68.52	41.51	78.85	39.74	0.345	0.25
MP80 (watts)	35.88	22.18	46.85	23.89	0.043*	0.49c
PP80 (watts)	57.99	33.75	68.42	34.43	0.043*	0.31c
Agility (s)	33.59	8.30	32.97	5.66	0.686	0.07
MAP (watts)	182.00	32.03	194.40	31.50	0.043*	0.39c
MRAP (watts/kg)	3.14	0.52	3.25	0.46	0.080	0.22
AAP (watts)	132.40	50.22	148.80	55.12	0.043*	0.33c
RAAP (watts/kg)	2.23	0.66	2.46	0.79	0.043*	0.34c
Fatigue index (%)	47.20	21.24	38.20	14.82	0.138	0.42
ESSWM (m)	3.60	0.87	4.10	1.01	0.043*	0.57b

**p* 0.05 (Wilcoxon). b medium effect size, c small effect size, *SD* standard deviation, *ES* effect size, *MIVC* maximum isometric voluntary contraction, *RM* maximum dynamic voluntary contraction, *MP* mean of muscle power, *PP* peak of muscle power, *MAP* maximal anaerobic power, *MRAP* mean relative anaerobic power, *AAP* absolute anaerobic power, *ESSWM* explosive strength of scapular waist muscles

was responsible for inducing an improvement in the muscle power of the upper limbs; (4) Intervention with RT-induced improvements in the functionality of the upper limbs of people with SCI; (5) 12 weeks of intervention with RT significantly improved mental status and QOL for the aspects of anxiety, functional capacity perception, and social aspects.

The periodization proposed in the intervention increased the total training load over the weeks, even though the RPE remained between 7 and 9 during the 12 weeks. This result indicates that the participants adapted to support a greater workload. In this sense, we considered that the intervention was successful because, in addition to being safe, the fact

Table 4 Assessment of health status, functionality, quality of life, and mental status

	Pre		Post	*t*	*p* value	ES
	Mean	SD	Mean	SD		
Mental state						
Depression inventory	10.25	4.79	5.50	3.70	0.14*	0.99a
Anxiety inventory	14.00	3.74	4.00	3.56	0.006*	2.67a
Mental disorder (Srq-20)	1.50	0.58	1.00	0.00	0.15*	0.87a
Quality of life						
Functional capacity	23.00	27.52	37.00	20.80	0.006*	0.51b
Limitation physical aspects	60.00	54.77	70.00	41.08	0.59	0.18
Ache	69.80	22.50	71.80	25.54	1.00	0.09
General health status	69.00	16.81	71.00	19.17	0.31	0.12
Vitality	67.00	13.04	78.00	13.51	0.10	0.84a
Social aspects	67.50	20.92	97.50	5.59	0.006*	1.43a
Emotional aspects	66.67	47.14	86.67	18.26	0.28	0.42
Mental health	66.40	12.20	75.20	8.67	0.10	0.72b

**p* 0.05 (Wilcoxon). a: Large effect size; b: medium effect size

that the people involved in the study increased the total training load by four times leads to believe that positive neuromuscular adaptations occurring [23], with direct reflections on the individual's functional capacity.

The progressive volume and high-intensity RT were efficient to improve the participant's body composition, mainly in the increase of the total BMC and segmenting of the main stimulated regions, arms, and spine. Despite not inducing significant changes in other variables, the RT seems to contribute to maintaining body composition, especially BMC, BMD, LM, FM, and T-score in different regions. Our results point to a reduction in the total LM; however, as can be seen in Table 2, this reduction probably occurred in a region not stimulated by the RT, for example, the lower region, and such reduction impacted the total, because when evaluating LM of arms, not differences occurred. It is well exemplified in the study of Kaya et al. [24], who noted that, as the SCI symptoms are aggravating, the BDM decreases proportionally, then it could be an influencing factor in the cases of experimental research such as the present study that deals with the likelihood of body composition changes in the participants [24].

People with SCI tend to be classified as sedentary and to lose SCI and BMC [25]. Along the same lines, the study by Astorino et al. [26] showed that an intervention with physical rehabilitation exercises aimed at the lower body in people with paraplegia for 6 months was able to improve the BMD of the spine but not the femur. Astorino et al. [26] concluded that, despite not reversing the loss of bone mass, the exercise intervention was able to attenuate the loss of bone mass in people with SCI. Thus, it is reasonable to think that 12 weeks of HIRT helped to maintain BMD and improve BMC, being a health promotion and disease prevention strategy (fractures and/or bone degeneration, for example) to be considered for people with SCI. Even in the case of people with previous experience with RT for at least a year, we also observed a reduction in SCI psychological and physical damage, accompanied with improvements in BMC, revealing that the RT protocol's efficiency in protecting these people from health complications provided by the muscle disuse after spine cord trauma.

In addition, it should be noted that the T-score of the entire body of the sample was classified as "osteopenia", going from − 1.28 to − 1.64 after the intervention. The T-score assesses bone mineral loss over life compared to reference values of someone of the same sex, at the peak of bone mass, values established as normal ≥ to − 1.0, osteopenia between − 1, 0, and − 2.5 and osteoporosis ≤ to − 2.5 [27]. This classification is understandable since SCI leads to an imbalance between bone formation and resorption, the latter being increased, and thus, bone resorption seems to play a fundamental role in most of the complications related to calcium metabolism observed after SCI, such as: osteoporosis due to immobilization, fractures, hypercalcemia, and development of kidney stones [25].

However, osteopenia results from the high loss of bone mass observed in the lower limbs since the value of the T-score of the femur (− 2.78) was higher than that found in the spine (− 0.78). This greater loss of bone mass in the lower limbs can be explained by the lack of mechanical stimulation on the femur and tibia, which are regions rich in trabecular bone [28], which end up experiencing a quick monthly bone loss of 4% in the first years of injury in areas of trabecular bone and 2% per month in areas with a cortical predominance [28]. Although the spine is made up mostly of trabecular bone, bone loss does not occur to such an extent, as it is responsible for supporting the body's weight constantly in the wheelchair, generating greater specific mechanical load and, thus, promoting increased osteogenesis in this region [28].

Thus, the increase in BMC found and the maintenance of BMD in the femur and spinal column can lead to fracture prevention and reduction, as well as reduce the speed of bone loss caused by inactivity and by age [26]. Although different alternative strategies are needed to reverse osteoporosis, RT can be included as a potential method of physical exercise for the prevention to prevent and recover the SCI patient's bone [8].

The progressive volume and HIRT increased the muscle power of the upper limbs of people with SCI. Few experimental studies have evaluated the RT effects on the muscle power of the upper limbs of people with SCI [6, 9, 23, 29]. The reduction in muscle power may be related to the degeneration of type II muscle fibers, with loss of phasic motor units [30, 31]. This reduction in muscle power in people with SCI as well as in the elderly who lose through the aging process can induce a reduction in functionality [31, 32]. On the other hand, the improvement in muscle power, especially those of greater intensity, will directly contribute to improving the performance of their ADLs, and in particular, tasks that may require a higher speed component or a force majeure component, such as transfer body weight and wheelchair propulsion on a slope, which will require repeated high-intensity muscular efforts of the upper extremities [33]. Thus, RT seems to indirectly contribute to improving the functional capacity of people with SCI and thus reversing some of the deleterious damages of this condition.

Functionality indicators were evaluated in the participant's upper limbs, and it was found that there was an improvement in functionality evaluated by anaerobic and power of upper limbs in hand-held cycle ergometer in this body segment of the people with SCI, besides preserving the functional agility for a period of 12 weeks. These adaptations are approximated to the cyclic movement of touching the wheelchair, thus, being specific to the requirements of the tasks to those experienced on a daily life of the person with SCI [34]. Similar results were found with improved anaerobic power in a study by Slade et al. [35], with elderly people who underwent traditional RT for 12 weeks, in which an increase in anaerobic power was observed when compared to the control group. The results suggest that RT affects muscle quality, leading to an increase in physical function resulting from increased anaerobic power [35]. Additionally, Jacobs [36] compared two groups of people with paraplegia, one who underwent aerobically and resistance training with a hand cycle ergometer and the other who underwent only RT, both for 12 weeks, and found an improvement in the anaerobic power of the upper limbs when tested by the Wingate test, in both exercised groups, showing that in this case, RT was too efficient as aerobic plus RT to improve the anaerobic power of the patients [36].

In summary, the results demonstrate that the RT improved the functional indicators (anaerobic power and explosive strength), which can improve the functional capacity of people with SCI. The progress of functional capacity will enable the individual to perform their ADLs with greater autonomy, and this may impact their QOL. The study results show an evolution of functional capacity and social aspects as dimensions of QOL after the intervention. Even in individuals already trained, the proposed intervention induced changes that resulted in an improvement in QOL. It is possible to observe an evolution in the dimension" functional capacity" of QOL, a fact that corroborates the results found in the evaluation of muscle power and indicators of functionality in the upper limbs. Likewise, there was an improvement in the "social relationship" dimension of QOL. A possible explanation for this result may be related to the benefits of regular physical exercise on symptoms such as depression and anxiety, in addition to providing distraction, self-efficacy, and improving the intrinsic capacity of the individuals to look for more social interaction [37]. Other similar results were the improvement in the symptoms of anxiety and positive changes in the post-intervention classification of symptoms of depression and mental disorders in SCI patients.

Thus, HIRT seems to be an efficient strategy to improve mental health and QoL perception. Hicks et al. [38] found a positive correlation between muscle strength, muscle power, and QOL in a study that examined the effect of 9 months of resistance training, twice a week, with an average duration of 90–120 min, at an intensity of 70–80% of 1RM, on muscle strength, psychological well-being indexes, and QOL in people with SCI. The results showed increased muscle strength and improved psychological indexes, with reduced levels of stress and depressive symptoms, greater satisfaction with their physical functioning, less sensation of pain, and improvement of physical self-perception. Thus, the authors suggested that people with SCI can significantly improve their sense of well-being by participating in a structured exercise program and that exercise can be used as a therapeutic modality to improve physical and mental fitness [38]. In this way, RT is a possibility capable of increasing functionality by increasing muscle power and anaerobic power, improving body composition, as well as reducing psychological and physical damage, and improving social life that will directly impact the QOL of people with SCI. Such results of improvement in strength, power, and even QOL are commonly found in the literature in sedentary individuals and the acute phase of the injury, but in chronically trained are rarely found, denoting the possibility of using RT as a rehabilitation strategy to progressively improving muscle strength in people with SCI, even after many years of injury.

Despite the results found, the present study presented some limitations (or specificities) that must be considered when analyzing the results. The sample size was reduced

($n = 5$), which was represented in low statistical power (power = 0.10), however, the research sought ecological validity, trying not to change the participant's regional and social reality (e.g., people arrived by their own means to the place of intervention). The research did not include a control group; however, because it is a heterogeneous group, the comparison of results would be complex, and the comparison with the person him/herself makes the result more realistic, as well reported by Evans [39], that portray that particular population like SCI patients, when assigned to a control or placebo group have to small likelihood to achieve adaptations without suffer any type of intervention, thus, reinforcing the no need of controlling this specific type of research trial. In addition, we tried to control the group of participants through the level of habitual physical activity to ensure that the results obtained could be attributed to the intervention performed.

Conclusion

Based on the results obtained in the present study, it is possible to conclude that RT is an alternative for improving and maintaining body composition, developing muscle power, anaerobic power, and explosive strength of upper limbs that will impact functional capacity, promoting greater autonomy, with consequent improvement of QOL and mental aspects of the person with SCI.

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Declarations

Conflict of interest The authors declare to have no conflicts of interest in the manuscript.

Ethical approval All procedures of the study were made in accord with the Helsinki declaration.

Consent to participate All subjects participated voluntarily, signed the Free and Informed Consent Form and received information about the study, as determined by the Resolution 466/2012 of the National Health Council.

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