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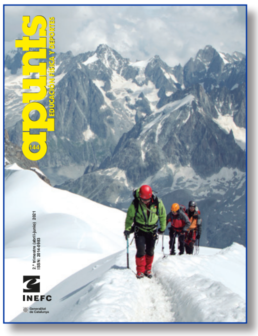

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Effect of Functional Strength Training on People with Spinal Cord Injury

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Abstract

The purpose of this study was to analyse the effects of functional training on muscle strength, functional capacity and quality of life (QoL) indicators in people with spinal cord injury (SCI). The sample consisted of five adult individuals of both sexes with SCI who did 12 weeks of functional training twice a week. Anaerobic power (ANP), movement agility, muscle strength and QoL were analysed before and after the training using the Wingate, zigzag, hand dynamometer and medicine ball throw tests and the WHOQOL-Bref questionnaire. The results showed an improvement in peak ANP ($p = .043$), relative peak ANP ($p = .043$), average ANP ($p = .042$) and relative average ANP ($p = .043$), as well as in peak agility ($p = .043$) and overall QoL ($p = .043$). It may be concluded that 12 weeks of functional training was sufficient to bring about improvements in ANP and agility with direct effects on enhanced functional capacity in people with SCI. The training programme implemented also helped to improve overall QoL.

Keywords: health, exercise, spinal cord, functional physical performance, quality of life.

Introduction

Spinal cord injury (SCI) is primarily caused by external trauma which may unexpectedly alter the injured person's life, leading to a certain degree of impairment in motor, occupational, recreational and social activities. This impairment is a causal factor and also results in reduced functioning and quality of life (QoL) (Rivers, 2018).

Conversely, physical exercise is one of the main drivers in rehabilitation and in promoting changes in the health of the public at large and also of people with SCI (Mendoza Laíz et al., 2001). As a factor for rehabilitation and health promotion, functional training seeks to enhance functioning and includes exercises drawing from natural movement rather than focusing on isolated muscle adaptations (the traditional approach) (Matos et al., 2017). This improvement observed in functional training is due to the fact that all natural movements occur in multiple joints through various planes of movement (Liu et al., 2014).

Functional training programmes are designed to simulate tasks or activities of daily living (ADLs) in order to make training adaptations more effective, for example to enable a person with SCI to perform transfers from the wheelchair to other locations without assistance. This type of training targets the neuromuscular system to stabilise the body through dynamic and isometric muscle actions in response to stressors such as gravity, ground reaction forces and momentum. Under the principle of specificity, training which replicates ADLs may be more effective in improving functional capacity (Liu et al., 2014).

Furthermore, greater functioning in people with SCI may be associated with increased ANP, as this will enhance agility (Gorgatti & Böhme, 2002), together with potential improvements in functional behaviour. According to The International Classification of Functioning, Disability and Health (ICF), functioning is determined by the health conditions and functions which an individual may perform in social participation and by the environmental setting in which they live (Farias & Buchalla, 2005). In turn, greater functioning may directly impact QoL (van Koppenhagen et al., 2014), as the domains that comprise QoL are directly correlated with functioning.

Functional training is therefore an option for promoting health, functional capacity and QoL for people with SCI. However, studies featuring functional training interventions in people with SCI are rare and are limited to rehabilitation studies and animal models (Fouad & Tetzlaff, 2012; Miranda et al., 2012). Additionally, studies evaluating the effect of functional training on ANP, agility, functional capacity and QoL in people with SCI might help to understand the potential effects of functional training on the organisation and restructuring processes of the body movements involved in ADLs, together with the potential use of functional training as a rehabilitation and health promotion strategy for people with SCI.

Consequently, the purpose of this study was to analyse the effects of functional training on muscle strength, functional capacity and QoL indicators in people with SCI.

Methodology

All the study procedures were conducted at the Strength Laboratory in the Physical Education Department of the Federal University of Viçosa, Brazil.

The study sample consisted of five people of both sexes with an SCI level between T4 and T11 and an average injury time of 18.6 years (Table 2). None of the five individuals had motor limitations in their upper limbs preventing them from performing ADLs.

The exclusion criteria were: a) having musculoskeletal or cardiometabolic problems limiting or contraindicating exercise; b) participating in other regular exercise programmes, and c) participating in less than 80% of the training sessions. Inclusion criteria were: thoracic SCI; traumatic SCI; being paraplegic; being clinically fit to participate in the study as determined by medical examination; having no upper limb paraparesis; having no previous strength training experience; and having no cognitive impairments which would preclude performance of the tests.

All the patients evaluated took part voluntarily, signed the informed consent form and received information about the study as specified in Decision 466/2012 of the National Health Council. The study was approved by the ethics committee for research involving human subjects of the Federal University of Viçosa, Minas Gerais, Brazil, under license number CAAE 51624715.2.0000.5153.

Training protocol

The intervention in this study was conducted following the guidelines for exercise prescription for people with SCI (Evans et al., 2015).

All the participants used their own means of transport (car) to get to the study site.

Before the intensity of the physical training was set, all the participants were assessed for agility, ANP and quality of life and they were asked about difficulties in performing ADLs. After this assessment, the participants tried out the strength training protocol so that the researchers could adapt the exercises to ensure that everyone was able to perform the same ones.

The participants did 12 weeks of functional training covering physical and motor skills: endurance, strength,

Table 1.
Training periodisation.

Week	1	2	3	4	5	6	7	8	9	10	11	12
Sets	2	2	2	2	3	3	3	3	3	3	3	3
Repetitions	8	8	10	10	8	8	10	10	10	12	12	12
RPE	5	7	6	7	6	7	6	7	7	6	7	7

speed, agility, balance, flexibility and coordination. The interventions were carried out twice a week and lasted approximately 60 minutes, in the course of which the participants performed eight exercises for the functional muscle groups with three sets of 10-12 repetitions per exercise.

Each session began with the participants covering 800 m in their wheelchairs as a warm-up. They then performed active stretching in the upper limbs and passive stretching in the lower region (this same routine was resumed at the end of each session). Afterwards, they did two exercises for approximately five minutes to stabilise their core (integrated unit consisting of 29 pairs of muscles which support the lumbo-pelvic-hip complex): holding an exercise ball with the hands and the elbows bent at 90° close to the trunk on which the trainer exerted a counterforce in order to unbalance the participant on the exercise ball, and barbell holding with arms at 90° to the trunk where the participants had to hold a barbell horizontally (parallel to the floor) with arms bent at 90°, with the barbell weighted at each end. Approximately 25 minutes of functional endurance exercises were performed after the stabilisation training. At the end of the session, the participants did another 800 m in their wheelchairs to make a total of 1,600 m for the session.

All the training was conducted involving the movements required for ADLs and was easy for the participants to perform and reproduce. The training was also designed so that all the exercises could be done in their wheelchairs.

The periodisation planning schedule was as follows: two sets of eight repetitions in the first week, increasing to two sets of 10 repetitions in the second week and three sets of 12 repetitions in the following weeks, with 60-second intervals between sets in the first two weeks, decreasing to 30 seconds in the following weeks (Table 1). All the participants performed the same exercises.

The training also consisted of four different exercises: chest press with elastic bands on a backrest on the participants' backs, the intensity increasing according to their perception; elbow extension with the shoulder extended to 180° and the elastic band secured to the wheelchair; shoulder horizontal abduction with elastic bands, and finally biceps curl with dumbbells.

The participants' load was monitored by Rating of Perceived Exertion (RPE) using the OMNI-RES scale (Robertson et al., 2003) with an intensity between 5 and 7. Participants were familiarised with the RPE scale in the pre-intervention period.

Although some studies show better results in acute and/or chronic high-intensity activities (Frotzler et al., 2008; Harness et al., 2008), low-to-moderate intensity loading was chosen due to the sedentary lifestyle and limited motor experience of the people with SCI included in the study.

The effects of this functional training protocol on the muscle strength, functional capacity and QoL of people with SCI were assessed by testing for anthropometry, hand grip strength, medicine ball throwing, ANP and agility, together with QoL perception before and after the 12 weeks of the intervention.

Anthropometry

Body mass was measured using a digital scale (Plenna, São Paulo, Brazil) with a capacity of 150 kg and an accuracy of 100 g. The limitation of the scale's length meant that the researcher's body mass had to be measured first, after which they stepped back on the scale holding the participant in their arms and the researcher's body mass was then subtracted from the total mass to calculate the participant's body mass.

Muscle strength

Hand grip strength was used as an indicator of peak dynamic strength and was assessed using a Jamar® hydraulic hand dynamometer (Sammons Preston Inc., Bolingbrook, IL, USA). The standard position proposed by the American Society of Manual Therapists entails testing with the individual seated in a straight-backed chair without armrests, with the elbow bent at 90° and the forearm in a neutral position. Three measurements were taken at one-minute intervals to avoid muscle fatigue and the highest value obtained in the assessments was used as the test result.

Upper limb muscle power was assessed using the medicine ball throwing test (Gorgatti & Böhme, 2002). A tape measure and a 2-kg medicine ball were used to perform this test. The tape measure was fixed to the floor perpendicular to the wheelchair with the starting point of the tape measure located at the projection of the back of the chair on the floor. The participant was seated in their own chair with their back against its backrest and with a strap to keep them attached to the back of the chair. The medicine ball was held close to the sternum with the elbows bent. On the evaluator's signal, the participant threw the ball as far as possible without lifting their back off the back of the chair. The throwing distance was recorded from the zero area to the point where the ball first touched the ground. Two throws were performed and the better result was recorded.

Anaerobic power (ANP)

ANP was assessed by the Wingate test (Franchini, 2002) using an Excite® Top upper body ergometer (Technogym, Cesena, Italy). The test lasted 30 seconds, during which the participant rotated the handles as much as possible against a fixed resistance set according to their body mass to generate as much power as possible in this period of time. The power generated during the 30 seconds was termed average anaerobic power (AVANP) and reflected localised upper limb endurance. The highest power generated, from 3 to 5 seconds, was termed peak anaerobic power (PANP) and provided information on the maximum mechanical power output of the participants' upper limbs. To minimise the possible effects of body mass on the test results, the PANP and AVANP values were relativised by body mass to calculate relative PANP (RPANP) and relative AVANP (RAVANP). The test also provided the fatigue index representing the decrease in performance of the evaluee during the test (Franchini, 2002).

Functional capacity

The functional agility test was used as an indicator of functional capacity in the participants in this study. Wheelchair agility was assessed using the adapted zigzag test (Texas Fitness Test) (Gorgatti & Böhme, 2003). The aim of the test was to cover the total distance of a 6 x 9 m rectangle, requiring changes of direction, as quickly and efficiently as possible. Each test subject used their own wheelchair to perform the test, which was marked out with five cones. On the evaluator's signal, the participant wheeled their chair around the course as quickly as possible. Five attempts were made five minutes apart. The first was for route reconnaissance, performed at low speed, while the second was for reconnaissance at high speed. The next three were considered valid for the test. A stopwatch accurate to hundredths of a second was used and the shortest time of the three attempts was recorded as the final result.

Quality of life

The instrument used to measure QoL was the Brazilian version (Fleck et al., 2000) of the World Health Organisation Quality of Life-Bref (WHOQOL-Bref) questionnaire featuring 26 questions across six domains: physical, psychological, social relationships, environment, spirituality/religion/personal beliefs and level of independence. The domains are represented by facets and their Likert-type responses range in levels of intensity (not at all-an extreme amount), capacity (not at all-completely), frequency (never-always) and evaluation (very dissatisfied; very satisfied; very poor; very good). In the responses, 1 stands for negativity and 5 for positivity and low evaluation percentiles mean low levels of QoL.

Statistical analysis

All the data were stored and processed using the statistical software IBM SPSS Statistics 23 and AI-Therapy Statistics BETA. The descriptive analysis was performed using the mean and standard deviation. Normality of data was determined using the Shapiro-Wilk test. The results before and after training were compared using the Fisher-Pitman non-parametric permutation test. Standardised measure of effect size was calculated by Pearson's r and was classified as small ($<.30$), medium ($.30-.50$) and large ($>.50$) (Cohen, 1988). All the statistical analyses were performed at a statistical significance level of $p<.05$

Results

Table 2 shows the profile of the research participants. The sample consisted of participants with chronic SCI, 60% women and 40% men, and with ages between 52 and 61 years in the case of women and 24 and 34 years for men. The lesions of all study participants are in the thoracic region. The causes are diverse and the average time injury was 18.6 years.

Table 3 shows the results for the assessment of muscle strength subdivided into ANP, muscle power and hand grip strength, and functioning as measured by the agility test. Functional training was seen to increase ANP. Furthermore, the functioning of the participants who took part in the functional training was higher after 12 weeks of training, as evidenced by the quicker times in the agility test.

Table 4 shows the results of the QoL assessment using the WHOQOL-Bref questionnaire. Functional training helped to improve the participants' overall QoL. Although no significant differences were observed between the domains, the physical domain was found to have an effect size considered large and the social relationship domain had an effect size classified as medium.

Discussion

The purpose of the study was to analyse the effects of functional training on muscle strength, functional capacity and QoL indicators in people with SCI. The main results were: 1) improvement of PANP, AVANP and RAVANP to body mass in the upper limbs of people with SCI; 2) increase in functional capacity; 3) improvement in overall QoL mainly by improving the physical domains.

The functional training was effective in increasing the PANP, AVANP, PRPANP and RAVANP of the upper limbs in people with SCI. Few intervention studies have evaluated the impact of exercise on ANP in people with SCI. In the study by Jacobs (2009) which compared two groups of people with paraplegia, one performing manual cycloergometer training and the other strength training and both for 12 weeks, an improvement in upper limb ANP was found in both exercise groups.

In the study by Nash et al. (2007), an increase in muscle strength and ANP was observed in people with thoracic SCI who did circuit strength training for 16 weeks, leading to a reduction in pain and increased shoulder functioning.

The data from this study are consistent with the results of the studies described above, suggesting that strength training can impact muscle quality and lead to greater physical functioning as a result of increased ANP.

Table 2.
Characterisation of the sample.

Individual	Sex	Age (years)	Injury time (years)	Cause of injury	Injury level
1	M	34	14	Motor vehicle accident	T5
2	F	61	51	Landslide	T11
3	M	24	3	Weapon accident	T9
4	F	52	18	Weapon accident	T4
5	F	55	7	Household accident	T6

Note. F: female. M: male. T: thoracic vertebrae.

Table 3.
Value comparisons.

	Pre		Post		*p*	ES
	Average	SD	Average	SD		
Body mass (kg)	56.85	8.11	56.49	8.84	.345	.29
MP (m)	3.29	1.02	3.43	1.03	.345	.29
HGS (kg)	40.90	14.42	43.10	14.99	.144	.46
PANP (watts)	133.40	51.58	147.20	48.64	.043	.64
RPANP (watts/kg)	2.29	0.63	2.56	0.55	.043	.64
AVANP (watts)	108.80	53.27	122.00	50.23	.042	.64
RAVANP (watts/kg)	1.86	0.72	2.13	0.67	.043	.64
Fatigue index (%)	28.80	15.41	30.40	14.99	.786	.08
Agility (s)	37.02	8.33	33.54	6.20	.043	.64

Note: SD: standard deviation; ES: effect size; MP: upper limb muscle power; HGS: hand grip strength; PANP: peak anaerobic power; RPANP: relative peak anaerobic power; AVANP: average anaerobic power; RAVANP: relative average anaerobic power.

Table 4.
Comparison of quality of life values of the people with spinal cord injury before and after the 12 weeks of functional training.

	Pre		Post		*p*	ES
	Average	SD	Average	SD		
Physical domain	3.14	0.26	3.43	0.21	.08	.55
Psychological domain	3.54	0.44	3.63	0.37	.416	.25
Social relationships domain	3.19	1.42	4.13	0.69	.109	.50
Environment domain	3.02	0.50	3.21	0.46	.285	.33
Perceived quality of life	3.80	0.44	4.00	0.00	.317	.31
Health satisfaction	4.40	0.54	4.20	0.44	.317	.31
Overall quality of life	3.22	0.40	3.60	0.17	.043	.64

Note: SD: standard deviation; ES: effect size.

The reduction in ANP may be related to the degeneration of type II muscle fibres and loss of phasic motor units (Kern et al., 2008). This decrease in muscle mass in people with SCI may lead to a reduction in the individual's functioning (Sezer, 2015). However, functional training would appear to promote anaerobic neuromuscular adaptations which bring about an improvement in ANP. It is consequently a strategy to be considered to reverse ANP losses and potentially enhance the functional capacity of people with SCI.

The functional training improved the agility of the participants in the intervention as measured by the adapted zigzag wheelchair agility test. Similarly, the study by Ozmen et al. (2014) showed that a 6-week explosive strength training programme at 50% of 1RM was effective in increasing speed and agility in wheelchair basketball players when added to their training routine. This appears to be the only functional training intervention in the literature to have assessed agility in people with SCI. There are agility measurements in wheelchair basketball (Fréz et al., 2015) and wheelchair handball (Silveira et al., 2012) players, but as they did not include any intervention it is difficult to compare them with the results found here.

Improved agility is associated with enhanced ANP (Ozmen et al., 2014). Agility, measured as the ability to make rapid changes of direction, is an important variable for the functioning of the person with SCI. The greater the agility, the more freely and safely the person can get about in their wheelchair. Conversely, impaired agility leads to a limited physical mobility which will make it impossible for the person with SCI to move autonomously and freely (Fechio et al., 2009).

Another plausible explanation for the improvement in agility might be associated with the ecological validity of this study, since in addition to all the assessments taking place in the participants' own wheelchairs, the functional training also stimulated the use of movements which simulated ADLs. Once again, functional training has proven to be an effective strategy in improving agility, thus confirming its relevance as a potential component in rehabilitation and health promotion for people with SCI.

The functional training may have been the starting point for the improvement in the overall QoL of the people with SCI who participated in this study and might be related to the physical and social relationship domains. Although no significant difference was observed in the physical domain ($p = .08$), there was a large effect size ($ES = 0.55$), suggesting that the intervention had an effect on this domain and also on the results seen in ANP and agility. Similarly, while no significant difference was observed in the social relationship domain between the assessment times ($p = .109$), a medium effect size ($ES = 0.5$) was found, an outcome which may be explained by the benefits of regular exercise for symptoms such as depression and anxiety, as well as distraction, self-efficacy and social interaction (Peluso & Andrade, 2005).

Hicks et al. (2003) found a positive correlation between muscle strength, ANP, agility and QoL in a study which examined the effect of nine months of twice-weekly strength training with an average duration of 90-120 minutes and at an intensity of 70-80% of 1RM on muscle strength, psychological wellbeing indices and QoL in people with SCI. Their results showed increased muscle strength and improved psychological indices with lower levels of stress and depressive symptoms, greater satisfaction with their physical functioning, less pain and improved self-concept. The authors therefore suggest that people with SCI can significantly improve their sense of wellbeing by taking part in a structured exercise programme and that exercise can be used as a therapeutic approach to augment physical fitness and physical and mental wellbeing.

Similarly, Mulroy et al. (2011) evaluated the effect of a 12-week, three times a week strength training programme with an average of 11 repetitions using low-intensity bodyweight exercise on the relationship of shoulder pain and movement in individuals with SCI. The results showed a two-thirds reduction in baseline shoulder pain levels that allowed the people to successfully perform social activities and ADLs, with a subsequent improvement in QoL and physical and social functions.

Consequently, functional training would seem to be a therapeutic approach likely to enhance functioning by increasing strength and ANP and also reducing psychological and physical impairment, while also improving social life, reflected in better QoL of people with SCI (Val-Serrano & García-Gómez, 2020). Practitioners involved in prescribing exercise for people with SCI are therefore recommended to consider prescribing functional training when the purpose of the exercise programme is to augment strength, functional capacity and QoL. Finally, the functional training used in this research is a strategy which can be implemented relatively straightforwardly as all the exercises performed are easy to reproduce and do not call for specialised equipment, which also attests to its practical usefulness in exercise prescription for people with SCI.

Notwithstanding the positive results found in this study, certain limitations (or specificities) were observed which should be considered when analysing the results. The sample size was small, meaning that the results cannot be generalised to individuals with different levels and degrees of SCI impairment. However, the research pursued ecological validity by not altering the regional and social circumstances of the participants and by including activities compatible with their daily routines. The limitations of the absence of a control group and not controlling for the participants' level of physical activity should also be considered. Nevertheless, all of them initially stated in an interview that they did not engage in regular physical exercise.

Conclusion

The results of this study led to the conclusion that 12 weeks of functional training was sufficient to yield improvements in ANP and agility with resulting direct effects on enhanced functional capacity in five people of both sexes with traumatic SCI between T4 and T11 and without paraparesis or other motor limitations in their upper limbs. Furthermore, the training programme implemented helped to improve overall QoL and enhance the participants' physical and social relationships domains. These results suggest that functional training is a strategy that should be considered, as it increases the functional capacity and QoL of people with SCI with similar motor and health conditions to the sample studied in this paper.

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