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ORIGINAL ARTICLE

Effects of resistance training on strength, pain and shoulder functionality in paraplegics

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Study design: Time series design.
Objectives: To determine the effects of a shoulder resistance training programme on isokinetic and isometric strength, body composition, pain and functionality in paraplegic subjects.
Setting: University of Valencia, Valencia, Spain.
Methods: A total of 15 subjects with thoracic spinal cord injury (SCI) performed three testing sessions with an 8-week period between the sessions. Subjects were not disturbed between the first and the second testing sessions. Subjects performed an 8-week resistance training programme after the second testing session. Variations in isometric and isokinetic shoulder muscle strength, body composition, reported pain and shoulder functionality were evaluated.
Results: The training programme produced a significant increase ($P<0.05$) in the isometric and isokinetic strength of several shoulder movements as well as an increase ($P<0.05$) in arm fat-free mass and a decrease in arm fat mass (FM). Furthermore, reported pain was decreased, ($P<0.05$) and upper-limb functionality was increased ($P<0.05$).
Conclusion: Implementing resistance training programmes as physical therapy in SCI subjects effectively increases strength, muscle mass and upper-limb functionality, whereas decreasing FM and pain perception.

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Keywords: pain; paraplegia; rehabilitation; shoulder; resistance training

INTRODUCTION

People with spinal cord injury (SCI) are usually in poor physical condition, mostly because of sedentary habits.[1] This circumstance may be one of the reasons for greater comorbidity and mortality as a result of cardiopulmonary and metabolic diseases compared with an able-bodied population.[2] Many papers have been published, in which resistance training programmes have been implemented to improve metabolic and cardiopulmonary system functions in SCI patients.[3–5]

Alm *et al.*[6] found that 91% of studied SCI patients suffered from chronic (that is, more than 3 months) shoulder pain. This pain is partly the result of overburdening the joint in the everyday life of these patients. This medical condition worsens over time because of patients' excessive use of their shoulder structures.[7] People with SCI must use their upper extremities as load limbs, because they often transfer their own body weight and propel a wheelchair. These activities require a muscle solicitation of nearly 50% of one repetition maximum (1RM), and these repeated high loads can lead to the development of upper-limb pain,[8] with the shoulder being the most problematic joint.[7]

Although a good balance of the periscapular muscles is recommended to avoid upper-limb injuries and/or pain,[9] few studies have sought to improve this balance.[2,10,11] Even though nearly all published studies found significant differences after implementing a training programme, the vast majority did not include a control group in their study design. Furthermore, the only study that included a control group[12] had a resistance training programme that included activities related to nutrition and videogame ergonometry, making it impossible to determine which improvements were attributable to resistance training. Except for two studies,[2,12] improvement in strength because of training has been assessed by measuring the maximum strength (that is, 1RM) exerted by the use of free weights and/or conventional muscle machines. In our opinion, this type of assessment provides less information and has a greater error margin than other measurements that use more advanced technology (for example, isokinetic devices).

Therefore, the main purpose of this study was to determine the effects of a resistance training programme on isokinetic and isometric strength. We also assessed the effects on body composition, reported pain and functionality of paraplegic subjects.

MATERIALS AND METHODS

Study design and general procedures

We employed a time series design with three testing sessions. Eight weeks elapsed between each testing session. In the period of time between the first and second sessions, the subjects did not adhere to a training programme. The participants carried out resistance training between the second and third testing session (Figure 1).

Before starting the first measuring session, subjects completed a session to become familiarised with the experimental procedures. Subjects were

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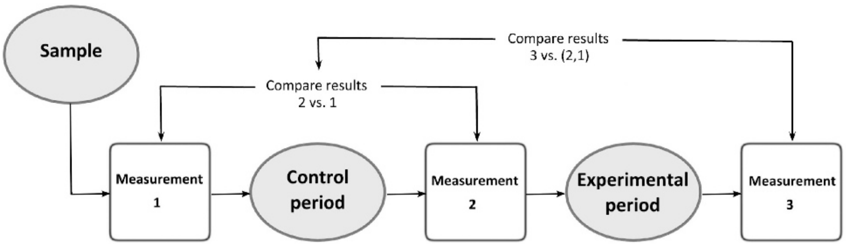

Figure 1 Study design. Comparisons between measurements were performed by means of difference planned contrast.

instructed not to perform strenuous activities or to take stimulants (for example, coffee) for 48 h before the testing sessions.

Subjects filled out the Wheelchair Users Shoulder Pain Index (WUSPI) and the Disabilities of Arm, Shoulder and Hand (DASH) questionnaire at each session. Body composition was evaluated immediately after the questionnaires were completed. Finally, isometric and isokinetic strength tests were completed in the same testing session. The same research team made all of the measurements.

Participants

A total of 15 men with chronic thoracic SCI were recruited from an outpatient clinic to participate in the study (Table 1). All of the subjects suffered complete motor loss in the lower limbs (that is, grade A or B on the American Spinal Injury Association scale) and were full-time manual wheelchair users. Subjects were excluded from the study if they met any of the following criteria: (i) cognitive, cardiovascular and/or muscle-skeletal disorder; (ii) presence of sacrotuberal ulcers; (iii) motor or sensory disorders in the upper limbs; or (iv) participation in resistance training programmes or sports competitions in the previous 6 months.

All subjects signed a written consent to participate in the study. The Institutional Review Board of the University of Valencia approved the study.

Torque measures

Isokinetic and isometric torque were measured during shoulder flexion–extension, abduction–adduction and internal–external rotation of the dominant arm using an isokinetic dynamometer (Biodex System 4, Biodex Medical Systems Inc., New York, NY, USA). All subjects performed the exercises in the same order (that is, external–internal rotation, flexion–extension, abduction–adduction). For each movement, subjects performed three isometric strength trials of 5 s for each movement. There was a 30-s recovery period between each isometric trial. After 3 min of rest, participants performed a concentric isokinetic trial of five repetitions at two different speeds (that is, 60 and $180^\circ \cdot s^{-1}$). A 3-min recovery was established between each pair of movements.

For subject placement and attachment, we followed the recommendations of the Biodex User's Guide (Biodex Pro Manual, Applications/Operations; Biodex Medical Systems Inc., Shirley, NY, USA, 1998) for each exercise.

Body composition measures

Body composition measures were performed by dual-energy X-ray absorptiometry (Hologic Discovery Wi, Hologic Inc., Bedford, MA, USA) at the whole body. Subjects were asked to lie in a supine position and to remain still. Post-acquisition analysis was completed using the adult whole-body software module (QDR v.12.3, Hologic Inc., Bedford, MA, USA). Fat mass (FM) and fat-free mass (FFM) of the arms and thoracic cage were calculated.

Pain assessment

To assess shoulder pain during everyday activities, patients filled out the performance-corrected WUSPI (PC-WUSPI). This questionnaire has 15 items to measure shoulder pain during transfers, wheelchair mobility, personal care and general activities. For each item, scores range from 0 (lowest pain) to 10 (worst pain ever experienced). The maximum possible score is 150.

Table 1 Participants clinical profile

Subject	*Age (years)*	*Weight (kg)*	*Height (m)*	*BMI ($kg\,m^{-2}$)*	*NLI*	*Evolution time (months)*	*Aetiology*	*Baseline WUSPI (score)*
1	45	70	1.71	24.10	T4	74	Traumatic	38.5
2	40	77	1.77	24.66	T11-12	236	Traumatic	0
3	36	96	1.88	18.16	T4-5	221	Tumoral[a]	0
4	40	64	1.50	32.18	T12	488	Traumatic	0
5	47	72	1.66	22.04	T4-5	219	Tumoral[b]	29.2
6	48	77	1.69	27.23	T12	21	Traumatic	10
7	51	78	1.60	27.77	T6	111	Traumatic	0
8	28	73	1.71	25.09	T5	12	Traumatic	11.6
9	70	51	1.71	17.58	T5-6	577	Traumatic	0
10	37	114	1.84	33.87	T4	75	Traumatic	0
11	39	85	1.68	30.11	T12	205	Traumatic	11.6
12	36	88	1.73	29.54	T11-12	62	Traumatic	16.5
13	26	70	1.75	22.85	T7	68	Traumatic	10.2
14	31	67	1.73	22.28	T4-5	138	Traumatic	10.6
15	30	76	1.84	19.51	T5	120	Traumatic	0

Abbreviations: BMI, body mass index; NLI, neurological level of injury; T, thoracic; WUSPI, Wheelchair Users Shoulder Pain Index.
All patients are Grade A in ASIA scale.
[a] Benign spinal cord astrocytoma, T4-T5 level with neurological stability.
[b] Benign spinal cord ependymoma, T4-T5 level with neurological stability.

Functionality assessment

Participants completed the DASH questionnaire as a measurement of upper-limb functionality. The questionnaire consists of 30 items, each with five possible answers ranging from one to five points depending on the difficulty the subjects experience when carrying out each of the activities described. After the participants completed the questionnaire, the scores were corrected to range from 0 (full functionality) to 100 (lowest functionality).

Resistance training

After the second measurement session, subjects started an 8-week resistance training programme that consisted of three training sessions per week. Each session was divided into a warm-up, main part and cool-down. During the warm-up, patients stretched their shoulder muscles for 10 min. During the main part of the session, subjects completed 3 sets of 8–12 repetitions of 8 different strength exercises designed for the shoulder muscles, paying special attention to rotator muscles. The following exercises were performed: lateral raise, latissimus pull down, horizontal row, biceps curl and internal and external rotation with 90° of abduction and in the neutral position.

All exercises were adapted to the participants' characteristics. Initially, the strength of the exercises was established as 70% of 1RM. Following an evaluation scale (from 0 to 10) of the perceived effort, strength was gradually increased. During the 8-week training period, subjects were instructed to adapt exercise burdens, so that their effort perception was about 7 or 8 points on the evaluation scale.[13]

Data reduction

Data analyses of the strength signals were performed using MATLAB 2010a (MathWorks Inc., Natick, MA, USA). For isometric trials, the average torque was calculated every 0.1 s for every repetition, with a window of 1 s. Of the 20 higher averages, those that showed a lower coefficient of variation were selected. Finally, the average of the three repetitions for each movement was calculated.

For isokinetic trials, both at 60 and $180^\circ \cdot s^{-1}$, we analysed the three central repetitions for each movement. We calculated the mean value of torque generated during each repetition within 50 and 90° for flexion, extension, abduction and adduction and within -10° and 30° for rotations. Finally, the mean value of the three central repetitions was used for the statistical analysis.

Statistical analysis

The statistical analysis was conducted by a blinded outcome assessor using PASW software, version 17 (SPSS Inc., Chicago, IL, USA). All variables complied with the assumption of normality. A multivariate analysis of variance (MANOVA) with repeated measures (testing time) was applied to establish the effects of resistance training on isometric and isokinetic strength and body composition. A repeated measure ANOVA was used to establish the effect of resistance training on pain and functionality. Planned contrasts were used to establish differences between the testing times. The level of statistical significance was set at $P<0.05$.

RESULTS

Isokinetic strength

The MANOVA revealed a main effect of resistance training ($F_{27,3}=9.75$, $P=0.042$, $\eta^2_p=0.99$) on the torque-related-dependent variables. For internal rotation, the ANOVA showed a main effect of testing time when the exercise was performed isometrically ($F_{1.19,16.65}=21.24$; $P<0.001$; $\eta^2_p=0.6$). Furthermore, for external rotation, there was a main effect of resistance training when the movement was performed isometrically ($F_{2,28}=13.6$; $P<0.001$, $\eta^2_p=0.49$), at $60^\circ \cdot s^{-1}$ ($F_{1.4,19.4}=42.37$; $P<0.001$; $\eta^2_p=0.75$) and at $180^\circ \cdot s^{-1}$ ($F_{2,28}=18.64$; $P<0.001$; $\eta^2_p=0.57$). Tables 2 and 3 show the results of the planned contrasts.

Regarding flexion movement, there was a main effect of resistance training in the isometric condition ($F_{1.03,14.38}=21.4$; $P<0.001$; $\eta^2_p=0.6$). This effect was also found in isometric extension ($F_{1,14.12}=8.49$; $P<0.011$; $\eta^2_p=0.38$) and in extension movement at $60^\circ \cdot s^{-1}$ ($F_{2,28}=8.75$; $P=0.001$; $\eta^2_p=0.38$) and $180^\circ \cdot s^{-1}$ ($F_{2,28}=8.73$; $P=0.001$; $\eta^2_p=0.38$). For both movements, the torque values were higher in the third testing session (see Tables 2 and 3).

There was a main effect of resistance training on isometric adduction ($F_{2,28}=4.49$; $P=0.02$; $\eta^2_p=0.24$), adduction at $180^\circ \cdot s^{-1}$ ($F_{2,28}=5.19$; $P=0.012$; $\eta^2_p=0.27$) and isometric abduction ($F_{2,28}=8.91$; $P=0.001$; $\eta^2_p=0.39$).

Finally, there was a main effect of resistance training in external/internal ratio at $60^\circ \cdot s^{-1}$ ($F_{2,28}=3.53$; $P=0.043$; $\eta^2_p=0.2$) and in flexion/extension ratio at $180^\circ \cdot s^{-1}$ ($F_{1.87,26.25}=5.18$; $P=0.014$; $\eta^2_p=0.27$). In the last testing session, the value of external/internal ratio was higher (closer to 1) than previous measurements, and the opposite was true of the flexion/extension ratio.

Body composition

The MANOVA showed a significant effect of resistance training ($F_{8,52}=2.96$; $P=0.008$; $\eta^2_p=0.31$) on body composition variables. Univariate contrasts revealed a main effect of testing time on arm FFM ($F_{2,28}=13.88$; $P<0.001$; $\eta^2_p=0.5$) and FM ($F_{2,28}=8.29$; $P=0.001$; $\eta^2_p=0.37$). The reduction in arm FM and the increase in arm FFM were both attributable to training (Figure 2).

Table 2 Differences in isometric torque between testing times

	Pre-test 1	*Pre-test 2*	*Post test*
Internal rotation (Nm)	39.9 (2.34)	40.69 (2.2)	47.89 (2.39)[a]
External rotation (Nm)	31.77 (1.89)	31.07 (1.85)	35.29 (1.96)[a]
External/internal ratio	0.8 (0.03)	0.76 (0.02)	0.74 (0.02)
Flexion (Nm)	61.39 (2.72)	61.53 (2.79)	68.52 (3.34)[a]
Extension (Nm)	72.07 (3.88)	72.18 (3.92)	81.69 (5.01)[a]
Flexion/extension ratio	0.87 (0.04)	0.87 (0.04)	0.87 (0.05)
Abduction (Nm)	50.75 (2.73)	48.60 (2.17)	53.65 (2.41)[a]
Adduction (Nm)	58.62 (3.47)	58.34 (4.06)	65.55 (4.23)[a]
Abduction/adduction ratio	0.89 (0.05)	0.86 (0.049)	0.85 (0.04)

Data are expressed as mean (s.e.m.).
[a]Indicates significant differences ($P<0.05$) between post test vs pre-test 1 and pre-test 2.

WUSPI and DASH scores

The ANOVA showed a main effect of testing time on DASH ($F_{2,28}=3.8$; $P=0.035$; $\eta^2_p=0.21$) and WUSPI scores ($F_{1.32,18.47}=7.46$; $P=0.009$; $\eta^2_p=0.35$). Results obtained for both questionnaires from the first two measurement sessions (that is, control time) did not vary (Figure 3). However, scores for both questionnaires decreased significantly ($P<0.05$) after training.

DISCUSSION

We observed that our patients had significantly increased shoulder strength in different scenarios immediately after the 8-week training period. We also saw an improvement in shoulder joint functionality, decreased pain perception and positive changes in body composition.

The results of our study are applicable in preventing shoulder injury and facilitating rehabilitation in the wheelchair user population.

Because of the increased life expectancy of paraplegic subjects, problems associated with increased longevity and joint wearing as a result of a more active lifestyle have become apparent.[14] Consequently, new strategies that consider musculoskeletal problems that may affect upper-limb functionality should be developed. Our resistance training programme is one such strategy. We were able to confirm that the proposed exercise routine had positive effects (that is, less pain and functionality improvement) on aspects related to rehabilitation in patients with mild shoulder lesions. Shoulder pain is present in a high percentage of wheelchair users,[6] and we are able to confirm that resistance training can improve symptomatology.

Our baseline strength figures at $60^\circ \cdot s^{-1}$, measured during the two first-testing sessions, were similar to those reported by Ambrosio *et al.*,[15] with the exception of the extension movement. However, strength produced during flexion, extension abduction and adduction by the subjects in our study was slightly greater than the values provided by Jacobs *et al.*,[2] although these measures were very similar to those of the external and internal rotation movements. Similarly, Bernard *et al.*[9] obtained moderately higher results for internal and external rotations (at 60 and $180^\circ \cdot s^{-1}$) than those achieved by the subjects in our study. Collectively, normal values in this and previous studies show strength development within the standard limits for the SCI population.[16]

Table 3 **Differences in isokinetic torque between testing times**

	Speed ($^\circ \cdot s^{-1}$)	*Pre-test 1*	*Pre-test 2*	*Post test*
Internal rotation (Nm)	60	37.35 (2.1)	35.93 (2.11)	38.69 (2.08)
	180	31.33 (2.7)	29.6 (2.05)	33.76 (2.01)[a]
External rotation (Nm)	60	25.33 (2.07)	25.01 (2.09)	29.11 (2.27)[a]
	180	22.13 (2.1)	20.34 (1.8)	24.21 (1.71)[a]
External/internal ratio	60	0.7 (0.072)	0.72 (0.07)	0.77 (0.06)[a]
	180	0.76 (0.09)	0.71 (0.06)	0.73 (0.05)
Flexion (Nm)	60	54.84 (3.51)	54.27 (3.17)	56.61 (3.32)
	180	42.64 (2.88)	42.57 (3.32	44.26 (3.12)
Extension (Nm)	60	59.76 (2.83)	56.69 (2.33)	64.66 (2.89)[a]
	180	40.24 (3.94)	43.51 (3.46)	49.7 (3.91)[a]
Flexion/extension ratio	60	0.92 (0.049)	0.96 (0.04)	0.88 (0.05)
	180	1.16 (0.09)	1.01 (0.06)	0.94 (0.06)[a]
Abduction (Nm)	60	41.81 (3.43)	42.39 (2.49)	42.44 (2.89)
	180	31.53 (2.68)	33.57 (2.26)	35.28 (2.96)
Adduction (Nm)	60	58.78 (3.42)	57.4 (2.55)	58.91 (2.85)
	180	44.73 (4.01)	48.27 (3.09)	53.06 (3.38)[a]
Abduction/adduction ratio	60	0.71 (0.05)	0.74 (0.04)	0.72 (0.04)
	180	0.72 (0.08)	0.71 (0.04)	0.68 (0.06)

Data are expressed as mean (s.e.m.).
[a]Indicates significant differences ($P<0.05$) between post test vs pre-test 1 and pre-test 2.

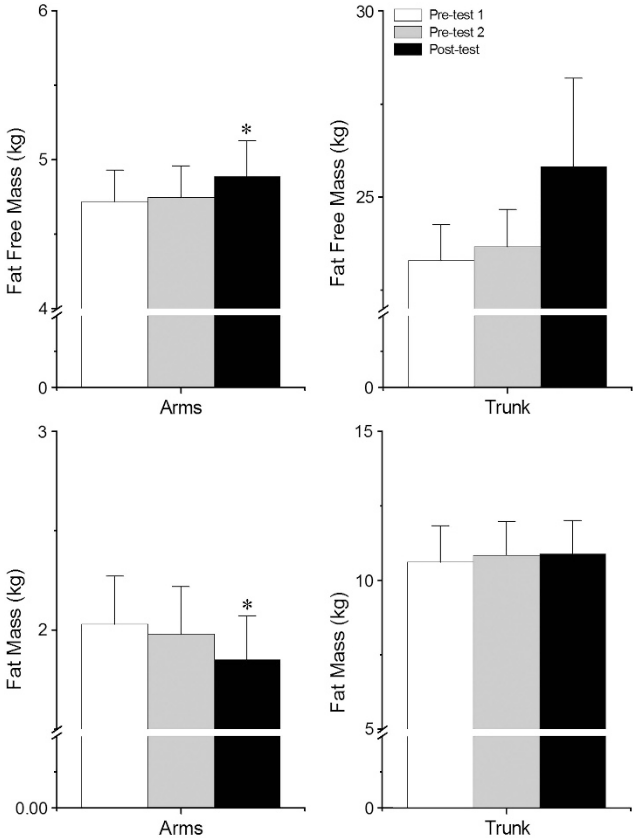

Figure 2 Body composition changes in the arms and trunk. Columns represent the mean, and error bars represent the s.e.m. * indicates significant differences ($P<0.05$) between post test vs pre-test 1 and pre-test 2.

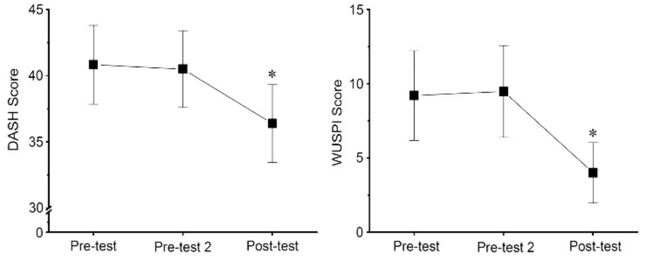

Figure 3 Shoulder disabilities and pain questionnaire scores. Black squares represent the mean, and error bars represent the s.e.m. * indicates significant differences ($P<0.05$) between post test vs pre-test 1 and pre-test 2.

We confirmed that our 8-week training programme had positive effects on isometric strength and improved all movements tested. However, isokinetic tests showed the specificity of the resistance training programme used; that is because improvements were made in external and internal rotation for both speeds, but only at 180° · s^{-1} in adduction and internal rotation.

These findings differ from those obtained in a previous study, in which concentric isokinetic strength at 60° · s^{-1} improved internal rotation, abduction, adduction and extension movements.[2] These inconsistent findings may result from the considerably different exercise designs that were used in these studies. Thus, our work focused on specific exercises for the rotator cuff (mainly monoarticular exercises), whereas Jacobs *et al.*[2] focused on general multiarticular exercises. Furthermore, Jacobs *et al.*[2] reported a greater percentage of improvement, with approximately 17% average flexion, extension, adduction and internal and external rotation improvement, whereas we only found a 7.5% average improvement for the same movements. The greater percentage improvement reported by Jacobs *et al.*[2] may be because of their use of a longer intervention time (4 more training months); greater increases in the transversal section of trained muscles were likely achieved during that period of time.[17]

On the other hand, we found increased muscle mass and decreased arm fat percentage. However, we did not find significant differences in trunk body composition, although there was a marginal increase in muscle mass of the area (see Figure 2). The data obtained in our study cannot be compared with previous data because no previous studies have examined the effects of resistance training programmes on these variables in SCI patients. Nevertheless, some authors found increased total weight, muscle mass and muscular transversal sections after an intervention with functional electrical stimulation cycling.[18] Increase in muscle mass owing to resistance training programmes have been also reported in studies in the able-bodied population.[19]

We also found that both DASH and WUSPI scores decreased, which suggest that pain decreased and functionality improved as a result of training. Previous studies have also reported improvements in pain perception, although the percentage was lower than in our study.[8] Regarding functionality, the increased figures obtained in our study are consistent with previously reported results.[10] At this particular point, two important questions concerning the results about function and pain should be addressed. On the one hand, only half of the subjects presented low pain level (their score was 38.5 of a maximum of 150). On the other hand, although the nature of the variables of the experiment were ordinal, we have used parametric tests (note that the variables were transformed into quantitative variables).

Although we have addressed some of the limitations of previous studies, our study nevertheless has some limitations that need to be considered when interpreting the results and/or planning future studies. First, we did not report measurements related to muscular activation, so we did not obtain information regarding the involvement of nervous system mechanisms in strength production processes. Furthermore, with a larger sample, the study power would have been increased, which might have allowed us to establish differences that could not be confirmed in our study.

CONCLUSIONS

In paraplegic people, isokinetic and isometric shoulder strength improves with an appropriate resistance training programme. Furthermore, resistance training increases muscular mass, decreases FM in the arms, improves functionality and decreases shoulder pain.

DATA ARCHIVING

There were no data to deposit.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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