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Elastic Band Training for Multiple Sclerosis Patients: a Pilot Study

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Abstract. [Purpose] This study examined the effects of six weeks strength training with elastic bands on different measures of strength manifestations, fatigue and functionality of multiple sclerosis (MS) patients. [Subjects] Sixteen MS patients (average age 44 years; range 33–56) with a diagnosis confirmed by a neurologist volunteered as subjects. They had mild to moderate disability and participated three times a week in a six-week elastic band strength training program. [Methods] Elastic band training progression was based on training volume using elastic bands of resistance of approximately 40% of a patient's previously measured maximal voluntary contraction. Outcome assessments included: maximal voluntary contraction with surface electromyography of the right and left legs, average and peak power with different submaximal loads of each leg, fatigue perception and functionality by the Timed Up-and-Go test. [Results] After the six-week strength training with elastic bands, average power with low load (98 N), peak power with very low load (49 N) and functionality had improved significantly. [Conclusion] A short and light training program using elastic bands can improve muscle function without injury and can be a good therapy for improving functionality of multiple sclerosis patients.
Key words: Exercise, Strength, Functionality

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INTRODUCTION

Multiple sclerosis (MS) is a demyelinating disease of the central nervous system (CNS) that leads to the destruction of myelin, oligodendrocytes and axons[1)]. It can result in impaired muscle function leading to weakness, fatigue and decreased ambulatory ability[2,3)]. These symptoms directly affect the daily activities of MS patients[4)].

Muscular weakness presented by MS patients does not have a clear etiology. Nevertheless, it has been demonstrated that this population presents muscular structural alterations[5,6)] and also neural alterations such as decreased motor unit discharge rates and incomplete motor unit recruitment[2,7)]. It is well known that these are key targets for muscle strength development.

Recent scientific literature has pointed out that physical exercise exerts positive effects on physical and emotional measures of MS patients. This may be due to exercise induced attenuation of functional capacity losses observed in this population. Furthermore, an individual training schedule might increase cardiorespiratory and muscle function while at the same time reducing fatigue and depression[8)]. On the other hand, detraining may induce opposite effects on functional capacity of MS patients[9)].

In a recent review, Dalgas et al.[9)] stated that muscular strength development in MS patients is more critical for a better functional capacity than aerobic capacity. Nevertheless, it is still not clear which is the best methodology to use when planning a strength training schedule for this population.

Studies with different training protocols have been carried out with MS patients. However, just a few of them have taken into account physiological mechanisms behind the improvements achieved by physical training such as neural adaptations or muscular structural adaptations in response to the resistance training. Surprisingly, none of those studies employed elastic bands in the training programs, considering the positive responses and ease-of-use previously demonstrated in other populations[10)]. Elastic bands have also been used for muscular power training by sportsmen[11,12)].

The aim of this study was to evaluate the effect of a training program with elastic bands on 1) maximal voluntary contraction (MVC) of the knee extensors with muscle activation analysis of the vastus lateralis (VL) and rectus femoris (RF), 2) muscle power, 3) fatigue and 4) functional capacity of patients with MS.

SUBJECTS AND METHODS

This study was approved by the Institutional Review Board of the University of León, and was conducted according to international standards[13]. The exercise program was offered to all patients with MS who were interested, so that no patient would be deprived of its possible benefits. The patient inclusion criteria in this study were: a disease diagnosis confirmed by a neurologist; ability to walk (with or without aid) at least 20 m without rest; absence of other diseases that might affect muscle function, and the absence of any episode of disease within the three months preceding the training program.

Only a small number of patients willing to undergo the evaluations also met the inclusion criteria, so the final study group contained only 16 patients.

All the patients belonged to the Multiple Sclerosis Association of León (León - Spain). The group consisted of eight women and eight men, whose level of disability was evaluated by a neurologist through the Expanded Disability Status Scale (EDSS), which ranges from 0, indicating a normal neurological result, to 10, indicating death due to MS. Patients scored from 1 to 5 (3.3 ± 1.6). Mean patient age was 44 ± 10 yr and the mean time since diagnosis of MS was 9.4 ± 3.7 yr. Subjects'mean height was 166 ± 7 cm and their mean body fat was 20.4 ± 6.3%. Nine of the patients had greater motor difficulty in the left leg. All patients underwent a medical evaluation to confirm their suitability and the absence of any contraindication for the physical exercise involved and all signed a written informed consent form before participation.

The experimental period lasted 10 weeks. The first two weeks were used to familiarize patients with the methods. The pre-evaluation took place at the third week, and post-evaluation was carried out at the tenth week. Between these evaluations, the subjects trained for 6 weeks. Before physical evaluation, a full medical check-up with baseline electrocardiogram was carried out. The evaluations consisted of anthropometry, MVC of the knee extensors with surface electromyography (sEMG) of RF and VL, knee extensors power assessment, Fatigue Severity Scale (FSS) and the Timed Up-and-Go test.

A load cell (Ergo Meter, Globus, Codogne, Italy) was used to determine the MVC of the knee extensors in a leg extension machine (Salter M-426, Tarragona, Spain), with the knee flexed at 140° and the hip flexed at 90°. The axis of the lever arm of the leg extension machine was visually aligned with the centre of rotation of the knee joint. A tibial pad was placed just proximal to the medial malleoulus on the lower extremity of each subject. The average distance from the axis of rotation to the tibial pad was 0.39 ± 0.02 m. This distance was carefully measured for each subject and it was used in both evaluation phases. Two 5-second MVC measurements of each leg were made, separated by 3 min recovery time. The best recording of the right and left legs were used in the analysis. Torque was calculated by multiplying the force by the external moment arm.

Electrode Positioning: Before starting the test, sEMG electrodes were attached to the skin of the subjects. The subjects were seated for skin preparation and sEMG electrodes placement (Ag/AgCl, Skintact, Austria). The skin was shaved and cleaned with ether to reduce its impedance. Once the skin was dry, subjects performed a low-intensity isometric contraction of each muscle in order to anatomically locate the muscles by palpation[14]. The electrodes were placed longitudinally to the muscle fibers direction in accordance with a previous report[15]. An interelectrode distance of 2 cm was used[16–18], and the reference electrode was placed in a neutral area away from the measuring units.

sEMG Signal Collection :Myoelectric raw signals were collected using the double differential technique from the VL and RF of subjects' right and left legs. The surface electrodes were connected to a 14-bit AD converter (ME6000 Biomonitor, Mega Electronics, Kuopio, Finland) by preamplifying cables with a gain of 305 (Mega Electronics, Kuopio, Finland). The total common mode rejection (CMRR) was 110 dB, and data were low-pass filtered (8 - 500 Hz) and sampled at 2000 Hz before being stored on a memory card (compact flash memory, 256 MB). Data were then transferred to and stored in a computer for further analysis.

sEMG data analysis: sEMG data analysis was performed using MegaWin V 2.21 software (Mega Electronics, Kuopio, Finland). The first five seconds of the isometric maximal test were chosen for data analysis with the "Marker Test" provided by the aforementioned software. sEMG raw data was averaged (aEMG) in order to obtain the maximal activation of the sEMG signal. Single spectrum averaging was also performed to obtain the mean frequency power (MPF) from the data of the 5 seconds of the isometric test.

Power was evaluated using a position transducer (Real Power, Globus, Codogne, Italy) at a sampling rate of 100 Hz. The transducer allowed recording the displacement of the load-plates across the knee's range of movement (90° to 180°). Thus, the power (force x velocity) was monitored and recorded throughout the movement during each repetition of the protocol. The testing protocol consisted of 8 unilateral-fixed-load repetitions (49, 98, 147 and 196 N). The load was randomized to avoid possible fatigue bias. The recovery time allowed between sets was 3 minutes. Subjects were asked to performed the concentric phase of each repetition as fast as possible, while the eccentric phase had to be done in a control way. To avoid possible inertia bias in data collection subjects' legs were fixed to the lever arm of the leg extension with Velcro® straps.

Peak power: For peak power data analysis the average of the three best repetitions was taken into account for each load and patient.

Average power: For average power data analysis all the repetitions within the range of movement were taken into account for each load and patient.

Table 1.

Training Weeks	Sets	Execution time per exercise (s)	Recovery time between exercises (s)
1–2	1–2*	30	30
3–4	2–3*	30– 45	30– 45
5–6	1–2*	45– 60	45– 60

Training protocol. *depending on fatigue self-perception.

Table 2.

Variables	Pre-training period			Post-training period		
	n	Right leg	Left leg	n	Right leg	Left leg
MVC (N)	12	306.3 (185.2)	307.5 (167.8)	12	327.3 (167.8)	306.5 (136.1)
Torque (Nm)	12	121.6 (74.4)	121.9 (67.1)	12	129.8 (63.5)	121.4 (56.1)
MPF RF (Hz)	12	90.2 (18.6)	89.1 (18.8)	11	82.5 (12.3)#	86.2 (13.0)
MPF VL (Hz)	12	77.4 (17.7)	82.9 (16.1)	11	81.5 (14.7)	63.8 (16.2)¥
aEMG RF (mV)	12	167.5 (135.7)	232.3 (256.9)	11	308.2 (276.2)#	264.4 (272.3)
aEMG VL (mV)	12	182.7 (177.1)	170.5 (121.4)	11	233.5 (302.4)	232.9 (258.0)
FSS	12	32.6 (9.4)		11	27.6 (7.6)	
Up-and-Go test (s)	12	7.5 (2.9)		12	5.9 (2.0)*	

Values measured at pre- and post-training for the right and left legs. Mean (SD); MVC maximal voluntary contraction; MPF mean frequency power; RF rectus femoris; VL vastus lateralis; aEMG averaged electromyography; FSS Fatigue Severity Scale; *Significant difference between pre- and post-training; #Significant difference between pre- and post-training of the right leg; ¥Significant difference between pre- and post-training of the left leg; p<0.05.

To evaluate fatigue perception the Fatigue Severity Scale (FSS) was used[19]. This is a nine-item scale scored from 1.0 (least fatigued) to 7.0 (most fatigued). The maximum score is 63, which is considered as the highest fatigue perception. The FSS assessment was done before pre- and post-training.

The Timed Up-and-Go test was carried out as previously reported by de Souza-Teixeira et al.[20] for MS patients. This test measures the time taken by a person to stand up from a standard chair, walk a distance of 3 m, turn, walk back to the chair, and sit down again. This test was administered 2 times and the best (lowest) score for each test session was used in the analysis.

The resistance training program was performed in a circuit fashion with progressive volume increments in each training session, as shown in Table 1. Subjects exercised 3 times per week for 6 weeks with at least 48 h between each training session. After a warm-up, subjects performed from 1 to 3 sets of 8 different exercises with elastic bands: leg-press, bench-press, rowing, half-squat, leg-curls, lunges and abdominals. Exercise time performance was between 30 and 60 seconds with an equal recovery time. Each training session ended with cooling down and stretching exercises. A strain gauge was used in order to determined the resistance offered by each elastic band. In this study, three elastic bands were used: 98, 147 and 196 N. Subjects trained with an elastic band corresponding to approximately 40% of the MVC obtained in the pre-training strength evaluation.

Standard statistical methods were used to calculate the mean and standard deviation. Spearman's product moment was used to express the correlation coefficients. Significance of differences was analyzed by Wilcoxon's non-parametric test. The Mann-Whitney test was used for pair-wise comparisons between left and right legs. A value of $p<0.05$ was regarded as significant.

RESULTS

Of the 16 patients initially recruited only 12 (7 women and 5 men) completed the whole training schedule because of personal reasons such as work schedules. Participants did not have any disease episodes during the study. Not all of patients were able to perform the power tests with the two highest loads. However, training increased their capacity to perform the power tests with those loads (Table 3). As an example, with a load of 147 N, initially, just eight patients could do the test and at the end of the period training the entire group could perform it.

Maximal voluntary contraction (MVC) and torque group values are summarized in Table 2. No significant differences after training were observed for either of the legs.

Surface electromyography (sEMG) results are shown in Table 2. No significant differences were found in muscular activation between legs in the pre-training values. aEMG showed a significant difference for the right leg after training for RF ($p=0.008$). Significant differences were also found in MPF of the right leg for the RF ($p=0.014$) and in the left leg for the VL muscle ($p=0.026$).

Peak power values obtained can be seen in Table 3. Significant differences were found for the left leg at 49 N load after training ($p=0.023$). This variation represents an increment of 23.4%.

Average power values are shown in Table 3. After training significant differences were found for the left leg ($p=0.049$) at 49 N load, and for both legs at 98 N load ($p=0.013$ and $p=0.036$ for left and right legs respectively).

Table 3.

Variables	n	Pre-training period Right leg	Pre-training period Left leg	n	Post-training period Right leg	Post-training period Left leg
Peak Power (W)						
Load 49 (N)	12	40.5 (14.9)	40.5 (15.7)	12	44.4 (13.8)	51.8 (36.4)*
Load 98 (N)	12	75.4 (32.6)	75.4 (35.9)	12	78.8 (31.8)	78.3 (32.4)
Load 147 (N)	8	126.8 (34.0)	128.1 (44.7)	12	100.6 (43.0)	103.8 (50.7)
Load 196 (N)	6	170.6 (28.4)	176.6 (39.7)	9	138.6 (46.2)	140.9 (63.4)
Mean Power (W)						
Load 49 (N)	12	26.9 (9.5)	27.0 (10.0)	12	29.2 (8.2)	29.6 (9.5)*
Load 98 (N)	12	48.5 (16.9)	46.6 (17.8)	12	53.0 (18.0)*	51.5 (16.3)*
Load 147 (N)	8	79.6 (17.3)	77.3 (24.0)	12	70.4 (24.8)	67.9 (25.5)
Load 196 (N)	6	103.3 (16.7)	108.7 (18.6)	9	91.0 (19.8)	90.7 (31.6)

Values measured at pre- and post-training for the right and left legs. Mean (SD); *Significant difference between pre- and post-training; $p<0.05$.

FSS results are shown in Table 2. A 10.9% of fatigue reduction was found after training, though this difference was not significant.

The values of the Timed Up-and-Go test are summarized in Table 2. The results improved significantly ($p=0.002$) with training, with a reduction of –19.1% (an average of 1.6 s) in the time to complete the test.

DISCUSSION

To date, no investigation has reported the effects of a circuit training program with elastic bands on muscle strength measures, perception of fatigue, or on functional capacity of MS patients. This study has shown that a very short circuit training program with elastic bands generates modest improvements in power and an increase in functional capacity of MS patients. These results are of scientific interest for the development of new training methodologies aimed at ameliorating MS disease symptoms. Furthermore, elastic bands individualization can resolve economic and facility issues and achieve positive results in a very short time-period.

Similar results were found for both legs for MVC, which is quite surprising considering the great variability shown by MS patients' syntomatology. Surakka et al.[3] did not observe this similarity in torque results for the same muscle group, showing lower leg values of 121 ± 52 Nm and 77 ± 28 Nm for the right and left legs respectively. Pre-training torque values obtained in the present study are similar to the right-leg torque value reported in a previous study but MVC did not show any significant differences after training, a result which is in agreement with that of Zion et al.[10] for 8 weeks of elastic band training performed by the elderly. This difference may be related to training specificity, intensity or duration. Pre-training muscle activation showed the same trend for MVC without significant differences between legs. After training, significant differences for aEMG and MPF were observed in RF of the right leg. Results like these with increments in amplitude and decrement in MPF are related to muscular fatigue[21,22]. Surprisingly, our participants maintained their MVC values and their perception of fatigue appeared to diminish. However, it is important to note that the sample analyzed was small and showed great intersubject variation. Future studies are strongly recommended to clarify the muscular activation of MS patients.

Muscle power data indicate that the higher the resistance load the higher the power output within the range of 22–55% of MVC (percentage values of the fixed loads used in the power test). Two studies have previously reported the load-power output relationship in healthy population[23,24]. However, in MS patients the lack of scientific studies on this issue is noticeable. Moreover, there have been no homogeneity among the methods used to measure power outputs. We found one published study that had used the same device to assess the same muscle group in a bilateral way, with a corresponding load of 40% of MVC[20]. Comparing our results with that study, considering the sum of our values obtained with similar relative loads (40% of MVC) in both legs, our sample presented lower power values (184 W vs 240 W). This difference could be explained by the inter-subject variability since subjects' disability levels, ages and initial physical condition were similar.

After training, significant differences were observed in peak power of the left leg at 49 N workload, an increase of 23.4%. This could be related to the fact that left leg was less explosive than the right leg, being more susceptible to training adaptations at lower loads. Our results were lower than those of DeBolt and McCubbin[4] who reported an improvement of 37.4% in peak power, using weight training vests and ankle weights over 8 weeks. DeBolt and McCubbin used training progression based on intensity, while we used volume progression, which could partially explain the differences between the two studies.

To our knowledge, no previous study of MS patients has focused on average power measurements. There is also a lack of studies on resistance training with elastic bands and average power measurements in different populations. Significant differences were found for both legs at 98 N workload, 11% and 14% increments for the right and left legs, respectively. All participants were able to perform average power testing at this load, which could be a possible explanation for the increment. It is important to adjust proper working-load in order to improve power outcomes.

Approximately 85% of the MS patients suffer from fatigue[25]. However, it is still not clear which are the main mechanisms (central or peripheral) involved in fatigue of MS patients[2]. The FSS is a tool recommended for clinical trials and its ease-of-use[26]. Krupp et al.[19] stated that the FSS is sensitive to fatigue perception changes in MS patients. Our results are acceptable for the studied population. A study of MS patients[27] registered a score of 47 points among 40 patients and a score of 15 points among20 patients. Holtzer and Foley[28] reported a score of 44 points in a sample of 20 MS patients. Considering these results the subjects of our study presented a moderate perception of fatigue. Although, the 10.9% reduction after training was not statistically significant, our results are in line with those reported by other physical activity intervention studies[3,22].

Functional capacity is an important factor for daily living activities. MS patients often have compromised functional capacity, and it is a key variable when studying this population. Our baseline results showed less compromised subjects compared to those in the studies of Schuhfried et al.[29] and DeBolt and McCubbin[4] who also used the Timed Up-and-Go test for assessment. The higher mean age of the participants in the other two studies could be a possible explanation for this. The 19% improvement found in our study fell midway between the values reported by DeBolt and McCubbin[4] and Hale et al.[30], 12.7% and 25% respectively. This data confirms that elastic band training is a powerful tool for improving MS patients' functional capacity. Positive correlations were found for gains in the Timed Up-and-Go test and measures of strength such as: MVC (r=0.690) and peak power (r=0.719).

In conclusion, elastic bands can be useful tool when facility and financial issues are a problem for the conduct of a training program for MS patients. When specific training devices are not available, elastic bands can enhance the functional capacity of MS patients, which, in our view, is one of the main goals of conducting a training program for this special population.

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