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Original Article

Impact of a resistance training program on functional disability, pain, strength, and range of motion in individuals with chronic low back pain: A double-blind randomized clinical trial

EDUARDO BORGES[1], BRUNO MEZÊNCIO[2], JOÃO PEDRO PINHO[3], JÚLIO SERRÃO[4]
[1]College of physical education YMCA of Sorocaba – São Paulo, BRAZIL
[2,4]University of São Paulo – São Paulo, BRAZIL
[3]Moove Lab, São Paulo, BRAZIL

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Abstract:
Low back pain is a condition characterized by pain and discomfort in the lumbar and sacral regions. Non-specific chronic low back pain leads to functional disability, reducing work productivity and imposing in significant socioeconomic burden. This clinical trial implemented an eight-week resistance training program adapted for individuals with chronic low back pain. Training intensity was prescribed based on participants' perceived exertion, ranging from "easy" to "somewhat hard" (OMNI-RES SCALE 4 to 6). The study aimed to evaluate the effects of this program on pain, functional disability, maximal strength, muscular endurance, and spinal mobility. A significance level of $p \leq 0.05$ was adopted for all statistical analyses. At the end of the study, the resistance training group exhibited a 71.6% reduction in functional disability (25.0 ± 5.8 to 7.1 ± 5.4; p = 0.001, η_p^2 = 0.82), a 79.6% reduction in pain (5.9 ± 1.6 to 1.2 ± 1.1; p = 0.001, η_p^2 = 0.62), a 36.7% increase in maximal strength (58.2 ± 29.9 to 79.6 ± 31.5; P = 0.001, η_p^2 = 0.90), a 31.1% increase in trunk flexion range of motion (37.6 ± 8.3 to 49.3 ± 9.9; P = 0.02, η_p^2 = 0.23), and a 56.6% increase in muscular endurance time (35.3 ± 26.8 to 55.6 ± 35.8; P = 0.01, η_p^2 = 0.30). These findings suggest that a low-intensity resistance training program tailored for individuals with chronic low back pain effectively reduces pain and functional disability while enhancing maximal strength, muscular endurance, and trunk mobility.
Key Words*:* **Exercise, back pain, fragile people, low intensity training**

Introduction

Low back pain (LBP) is a condition characterized by pain and discomfort in the lumbar and sacral regions, specifically between the costal margin and the inferior gluteal fold, with or without radiation to the lower limb. When the pain persists for more than twelve weeks, it is classified as chronic low back pain (CLBP) (Airaksinen et al., 2006). Non-specific chronic low back pain (NSCLBP) accounts for more than 90% of all cases of LBP (Airaksinen et al., 2006).

Functional disability refers to the difficulties individuals experience in performing daily activities (Stucki et al., 2019). NSCLBP-related functional disability significantly reduces work productivity and has a major socioeconomic impact. Recognizing the global burden of this condition, a leading journal published a series of three articles addressing the issue, with the final article calling for urgent international action (Buchbinder et al., 2018; Foster et al., 2018; Hartvigsen et al., 2018).

Various forms of exercise have been proposed as treatments for NSCLBP (Owen et al., 2020; Searle et al., 2015), including resistance training (Kristensen & Franklyn-Miller, 2012). However, current literature does not classify traditional resistance training (RT) as sufficient to resolve functional disability and pain in individuals with CLBP (Grooten et al., 2022; Owen et al., 2020). This limitation arises from the heterogeneity of RT programs, many of which incorporate exercises and methods that deviate from conventional RT models (Bae et al., 2018; Cortell-Tormo et al., 2018; Verbrugghe et al., 2019; Steele et al., 2020; Grooten et al., 2022; Farragher et al., 2024). Additionally, some studies have reported that participants still exhibit moderate functional disability following RT interventions (Fairbank & Pynsent, 2000; Kell & Asmundson, 2009; Kell, Risi & Barden, 2011).

Functional disability in individuals with NSCLBP is typically assessed using self-report questionnaires, often supplemented by physical performance measures (Stucki et al., 2019). According to the Oswestry Disability Questionnaire, a score of ≥21% indicates moderate functional disability (Fairbank & Pynsent, 2000). Therefore, this study aimed to implement an eight-week RT program (American College of Sports Medicine, 2009), primarily composed of exercises recommended for individuals with NSCLBP (Tataryn et al., 2021) and performed at low intensity to accommodate vulnerable populations (Garber & Blissmer, 2011). A previous study by our research group demonstrated that a single session of this training model led to slight improvements in

Corresponding Author: EDUARDO BORGES, E-mail: eduardoborges@fefiso.com

pain and functional disability in individuals with NSCLBP (Borges et al., 2023). Based on these findings, we hypothesized that our experimental RT program, performed twice weekly for eight weeks, would reduce participants' functional disability from moderate to mild (<21%), while also contributing to pain relief and improvements in complementary physical functions such as maximal strength, muscular endurance, and spinal range of motion in individuals with NSCLBP.

Material & methods

Experimental Design

This was a double-blind, randomized, parallel-group experimental study, comprising an experimental group (EG) and a control group (CG). Both groups maintained their usual daily activities and work routines for eight weeks. However, the EG additionally participated in an eight-week experimental resistance training program. Participant recruitment for NSCLBP was conducted through online digital media and radio broadcasts in the city of Sorocaba, São Paulo. Sample size estimation was performed a priori using an inverse T-test, considering the primary outcome variable. Assuming 80% power, a 5% Type I error probability, and an expected variation of 15%, the calculation determined a minimum of 11 participants per group.

The study was approved by the Research Ethics Committee for human participants (CAAE: 51078721.5.0000.5500) and registered in the Brazilian Clinical Trials Registry (UTN: U1111-1273-0751). All participants provided written informed consent.

Participants

The experiment was completed by 27 participants of both genders, with 16 in the experimental group (EG) (7 men and 9 women) and 11 in the control group (CG) (2 men and 9 women). Inclusion criteria required participants to have experienced low back pain for more than three months, with at least two episodes per week; no diagnosis of a herniated disc confirmed by magnetic resonance imaging; be between 20 and 59 years old; have a functional disability score between 21 and 60 on the Oswestry disability scale; have a body mass index (BMI) of no more than 30; have not engaged in physical exercise in the past three months; and agree to refrain from using analgesic medication during the study.

Participants meeting these criteria underwent a final selection phase, during which they were evaluated by a physical therapist. At this stage, individuals with herniated discs, severe spinal pathology, and/or radicular symptoms were excluded. The baseline characteristics of the participants are presented in Table 1.

Table 1. Baseline characteristics of participants by group. $\bar{x}$ = mean; σ = standard deviation; t = T-test. p = associated probability. EG = experimental group; CG = control group; BMI = body mass index.

Variables	EG		CG		t	p
	$\bar{x}$	σ	$\bar{x}$	σ		
Age (years)	42.9	10.7	41.7	9.1	-0.30	0.761
Mass (Kg)	75.7	8.7	68.9	10.3	-1.84	0.077
Height (m)	1.68	0.06	1.67	0.07	-0.13	0.897
BMI (Kg/m^2)	26.8	2.5	24.6	2.8	-2.14	0.041
Duration of pain (years)	6.5	5.6	5.4	2.8	-0.68	0.498
Days with pain per week	5.2	1.2	4.6	1.4	-1.09	0.282
Disability (%)	25.0	5.8	27.2	8.7	0.78	0.441
Numeric pain scale	5.9	1.6	7.0	1.6	1.87	0.072
Maximum strength (kgf)	58.2	29.9	51.0	20.1	-0.69	0.490

Procedures

Initially, all participants in the Experimental Group (EG) and Control Group (CG) completed a functional disability questionnaire, rated their pain intensity on a numerical scale, and underwent maximum strength tests, as well as the Biering-Sorensen and trunk flexion tests. Subsequently, participants in the EG completed an eight-week resistance training program, while those in the CG maintained their usual daily routines. At the end of the program, both groups underwent reassessment. All procedures were conducted at the Faculty of Physical Education in Sorocaba, São Paulo.

Resistance Training Program

The experimental intervention lasted eight weeks (16 sessions in total) and was conducted in the gym at the Faculty of Physical Education in Sorocaba, São Paulo, under the supervision of three physical education professionals. Training sessions were held twice a week (Tuesdays and Thursdays), each lasting approximately 30 minutes. Participants performed five exercises in the following order: hex bar deadlift, rowing machine, chest press, back extension on a Roman chair, and lumbar flexion (abdominal crunches) (Figure 1). The cadence for muscle contractions was approximately 2 seconds for the concentric phase and 2 seconds for the eccentric phase.

Participants were instructed to breathe freely, avoiding breath-holding. During the abdominal exercise, exhalation was performed during the concentric phase.

During the first four training sessions, participants performed 2 sets of 10 repetitions for all exercises. From the fifth session onward, the hex bar deadlift, machine row, and machine bench press progressed to 3 sets of 10 repetitions, while the rest interval between sets remained 1 minute. At the end of each exercise, participants rated their effort using the OMNI-RES subjective perceived exertion (SPE) scale (Lagally & Robertson, 2006). During sessions 1 to 4, loads were adjusted to a maximum SPE of 6. From the fifth session onward, SPE was maintained between 4 and 6, except for back extensions on the Roman chair and abdominal crunches, which were performed using body weight.

In the final training session, a 10RM test was conducted to determine the maximum intensity at which participants completed the resistance training program. The 1RM load was estimated using the Brzycki equation (Brzycki, 1993) and converted into %1RM. At the beginning and end of each training session, participants rated their pain levels on a numerical pain scale. Subjective pain perception before each resistance training session (3.4 ± 1.9) was not significantly different from post-session pain perception (2.3 ± 1.8).

The program did not include warm-up or stretching exercises, nor did it allow additional exercises during the intervention period. By the end of the eight-week intervention, no injuries or accidents were reported. Only one participant withdrew due to a change in work schedule.

Figure 1. Exercises performed in the resistance training program: A) hex bar deadlift, B) rowing machine, C) chest press machine, D) roman chair exercise, E) abdominal crunches

Hex bar deadlift

The hex bar deadlift exercise (Figure 1A) began with participants in an upright position, holding the bar. They were instructed to flex their hips and knees until the bar reached at least knee height, then return to the upright starting position. Two participants who had difficulty keeping their heels on the ground used a wedge for support. The primary agonist muscles involved in the exercise were the quadriceps and gluteus maximus, while the spinal erectors and multifidus acted as stabilizers. During sessions 1 to 4, the exercise was performed with a load equivalent to 30% of the maximum voluntary isometric contraction, as determined by a strength test developed in our study. From the fifth session onward, the load was adjusted within a rating of perceived exertion (RPE) range of 4 to 6.

Rowing machine and Chest Press Machine

The rowing machine (Figure 1B) and chest press machine (Figure 1C) exercises were performed on TRC equipment (Pórtico, São Paulo, Brazil), with adjustments made to ensure optimal anatomical positioning for each participant, as determined by an experienced personal trainer. The primary agonist muscles targeted were the latissimus dorsi for the rowing exercise and the pectoralis major for the chest press.

Roman chair exercise

The lumbar extension exercise was performed on a 45° inclined Roman chair (Figure 1D) using body weight. Participants were positioned so that their anterior superior iliac spines rested on the support pad, stabilizing the pelvis and preventing hip movement. They began in a neutral position with their arms crossed over the chest, then flexed the trunk maximally during the descent phase before extending back to the starting position, avoiding lumbar hyperextension. The spinal erectors and multifidus served as the primary agonist muscles.

Abdominal crunches

The abdominal crunch exercise (Figure 1E) was performed on a mat, with participants lying in a supine position, hands placed behind the head, and elbows flexed. From this position, they were instructed to maximally flex the lumbar spine. The rectus abdominis was the primary agonist, while the external and internal obliques acted as synergists.

Data Acquisition

Functional Disability Measurement

Functional disability was assessed using the Oswestry Disability Questionnaire, a validated questionnaire comprising 10 items, each rated on a 0 to 5 scale. The total score, expressed as a percentage (0–100%), reflects the degree of disability in performing daily activities (Vigatto et al., 2007).

Pain Intensity Measurement

Low back pain intensity was measured using an 11-point Numerical Rating Scale (NRS), which assessed pain perception over the past week. The scale ranged from 0 (no pain) to 10 (worst imaginable pain) (Ferreira-Valente et al., 2011).

Maximum Strength Assessment

Maximum isometric strength was measured using a custom-designed device, consisting of a rectangular bar with an attachment point for a load cell, a steel base with a hook, and a chain. The design and validation of this apparatus were detailed in a previous study (Borges et al., 2023). Participants assumed a static position with knees and hips flexed, holding the bar at knee height. Upon the evaluator's command, they applied maximum force against the fixed resistance, ensuring no abrupt impact on the load cell. The test protocol included:

1. A 10-second submaximal contraction for familiarization.
2. Three maximum-effort contractions lasting 5 seconds each, with 1-minute rest intervals.
3. The highest force value, recorded in kilogram-force (kgf), was used for analysis.

Range of Motion (ROM) Assessment

Trunk flexion range of motion (ROM) was assessed during six repetitions of the lumbar extension exercise on the Roman chair. Participants performed maximal trunk flexion during the descent phase of each repetition. ROM was calculated as the difference in trunk inclination relative to the pelvis between the starting and final positions of each repetition. Kinematic data were collected using a camera recording at 90 fps (Logitech BRIO®) and processed with MyoVideo software (Noraxon®). Reflective markers were placed on the acromion, posterior superior iliac spine, anterior superior iliac spine, iliac crest, greater trochanter of the femur, and knee joint centre to ensure accurate motion tracking.

Isometric Endurance of the Spinal Erectors

The Biering-Sorensen test was used to assess isometric endurance of the spinal erector muscles, following established protocols (Demoulin et al., 2006). Participants maintained their trunk in a horizontal position, with their lower limbs and iliac spines supported on a test table. Arms were crossed over the chest and the test was terminated when participants were unable to maintain the position for more than 3 seconds. The maximum duration (in seconds) was recorded for analysis.

Statistical Analysis

Data normality and sphericity were assessed using the Kolmogorov-Smirnov test and Mauchly's test, respectively. Differences in pain perception and functional disability between groups and across evaluation time points were analyzed using a two-factor repeated measures analysis of variance (ANOVA), with group (experimental vs. control) and time (pre- vs. post-intervention) as factors. When necessary, the Student-Newman-Keuls (SNK) post-hoc test was applied. The significance level was set at 5% ($P < 0.05$), and partial eta-squared (η_p^2) was used to determine effect size, classified as small (0.01), medium (0.06), and large (0.14). All statistical analyses were performed using SigmaStat 3.5 software.

Results

Resistance Training Intensity

The comparison of ratings of perceived exertion (RPE) between the first and last resistance training sessions revealed a significantly higher RPE value for the lumbar extension exercise in the first session compared to the last session (5.5 ± 2.4 vs. 3.1 ± 2.4). Similarly, the abdominal exercise exhibited a significantly higher RPE value in the first session compared to the last session (2.6 ± 1.4 vs. 0.9 ± 1.1, $p < 0.05$). No statistically significant differences were observed for the hex bar deadlift, rowing, or chest press. Additionally, the percentage of one-repetition maximum (%1RM) achieved in the final training session did not differ significantly among the exercises (Table 2).

Table 2: Estimated percentage of one-repetition maximum (%1RM) and ratings of perceived exertion (RPE) during the resistance training program (mean ± standard deviation). @: significantly higher than all exercises in the first session (except for the hex bar deadlift); $: significantly higher than the last session of the roman chair and abdominal crunch exercises (p = 0.04); #: significantly lower than all values in both the first and last sessions (p = 0.03). No significant differences were found in %1RM.

Exercise	%1RM	RPE	
	Last Session	First Session	Last Session
Hex bar deadlift	39 ± 8	4.0 ± 1.2	4.2 ± 1.4
Rowing machine	39 ± 7	3.2 ± 2.1	3.6 ± 1.9
Chest press machine	41 ± 9	2.9 ± 2.1	3.5 ± 2.0
Roman chair exercise	-	5.5 ± 2.4 @ $	3.1 ± 2.3
Crunches	-	2.6 ± 1.4	0.9 ± 1.1 #

Functional Disability and Pain Intensity

Both functional disability and pain intensity showed significant reductions (Figure 2). Functional disability analysis revealed a significant interaction between group and time ($p = 0.001$; $\eta_p^2 = 0.81$). Functional disability was significantly lower after 8 weeks of resistance training (RT) in the experimental group (EG) (25.0 ± 5.8% to 7.1 ± 5.4%; p = 0.001, η_p^2 = 0.82) and was also significantly lower in the EG compared to the control group (CG) at the final time point (7.1 ± 5.4% vs. 27.1 ± 8.1%; p = 0.001; η_p^2 = 0.87).

Pain perception analysis (Figure 2) also revealed a significant group-by-time interaction (p < 0.001; η_p^2 = 0.55). Pain perception was significantly lower after 8 weeks of RT in the EG (5.9 ± 1.6 to 1.2 ± 1.1; p = 0.001, η_p^2 = 0.62) and was also significantly lower in the EG compared to the CG at the final time point (1.2 ± 1.1 vs. 6.7 ± 1.7; p = 0.001, η_p^2 = 0.74).

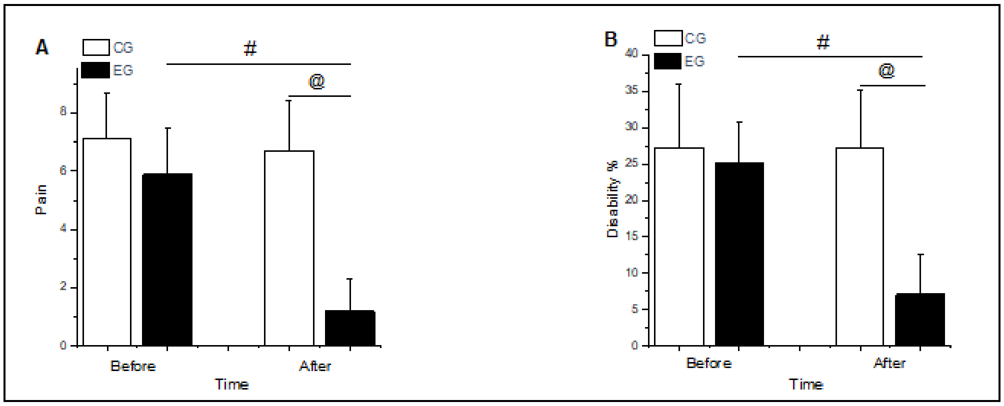

Figure 2. A) Pain perception. B) Functional disability. @: significantly lower value in the experimental group (EG) compared to the control group (CG) at the final time point ("After") (p = 0.001); #: lower value at the "After" time point compared to "Before" in the EG (p = 0.001). A significant group-by-time interaction was observed (p = 0.001).

Maximum Strength, Trunk Flexion, and Biering Sorensen Test

The results for maximum strength, trunk flexion, and the Biering-Sorensen test showed statistically significant differences (p < 0.05) (Table 3).

Table 3. Mean and standard deviation of maximum strength, trunk flexion, and Biering-Sorensen test variables, compared between the control and experimental groups at baseline and final assessments. Statistical probability (p-value), followed by partial eta-squared effect size (η_p^2), are presented for group, time, and interaction analyses. a: significantly higher value in the between-group comparison at the same time point; c: significantly higher value compared to the initial measurement within the same group.

Variable	Control		Experimental		p-value (η_p^2)		
	Initial	Final	Initial	Final	Group	Time	Interaction
Strength (kgf)	51.0 ± 20.1	56.5 ± 24.1	58.2 ± 29.9	79.6 ± 31.5[a,c]	0.16(0.92)	<0.001(0.90)	0.008(0.77)
Trunk flexion (degrees)	38.9 ± 14.7	37.9 ± 12.1	37.6 ± 8.3	49.3 ± 9.9[a,c]	0.213(0.21)	<0.001(0.23)	0.002(0.30)
Sorensen Test (s)	24.8 ± 30.4	26.4 ± 32.6	35.3 ± 26.8	55.6 ± 35.8[a,c]	0.10(0.58)	<0.001(0.30)	0.01(0.23)

Discussion

The light-intensity traditional resistance training program (39–41% of 1RM; RPE of 4–6) for individuals with non-specific chronic low back pain (NSCLBP) demonstrated significant reductions in pain intensity and functional disability, supporting our hypothesis that participants would achieve a mild disability classification (<21% on the Oswestry Disability Index). Following eight weeks of RT, we observed a 56.6% increase in trunk extensor endurance, a 31.1% improvement in spinal mobility, and a 36.7% increase in maximum strength (Table 3). Notably, there was a 71.6% reduction in functional disability and a 79.6% decrease in pain intensity (Figure 2).

Our resistance training program incorporated RPE control (OMNI-RES 4–6) for exercises such as the hex bar deadlift, chest press machine, and rowing machine, while the lumbar extension on the Roman chair and abdominal crunches were monitored but not subject to strict RPE control. An interesting finding from the RPE data (Table 2) is that the lumbar extension exercise had a significantly higher RPE compared to all other exercises in the first session but showed a notable reduction by the final session. This decrease in RPE may reflect the increase in maximum strength observed in our results (Table 3), as no external load was added to the lumbar extension exercise over the eight weeks.

Participants in this study were selected based on moderate to high functional disability levels (21–60% on the Oswestry Disability Questionnaire). However, after the intervention, they demonstrated a significant reduction to a mild disability level (7.1 ± 5.4%). In contrast, Kell and Asmundson (2009) reported that, after 13 weeks of resistance training, participants still exhibited moderate functional disability (24.2%). In a subsequent study, the same authors found that, even after 16 weeks of training at a frequency of 2, 3, or 4 sessions per week, participants still showed moderate disability levels, regardless of weekly frequency (Kell, Risi, & Barden, 2011). Their training programs incorporated 12 exercises (3 × 10RM) at intensities of 53–72% of 1RM, including a Superman exercise for spinal erectors (3 × 10 repetitions), with each repetition consisting of a 5–30 second isometric hold. When participants exceeded 30 seconds, additional load was added. Given these differences in training intensity and volume, we believe that the lower intensity and volume used in our RT program contributed to the greater reductions in functional disability and pain observed in our study.

In our study, pain intensity decreased by 79.6% (5.9 ± 1.6 to 1.2 ± 1.1). In contrast, Kell and Asmundson (2009) reported only a 38% pain reduction after 16 weeks (from 5.4 ± 0.9 to 3.3 ± 0.5), while a later study found a 28% reduction (from 6.05 ± 0.90 to 4.35 ± 0.95) (Kell & Asmundson, 2011). As discussed earlier, the differences in intensity, volume, and spinal erector-specific exercises may explain why our low-intensity approach yielded more substantial improvements in a shorter time. However, further research is required to determine the optimal intensity and volume of resistance training for NSCLBP.

Resistance exercises that primarily target the spinal extensors and hip muscles appear to be particularly effective for individuals with chronic low back pain (CLBP) (Tataryn et al., 2021). A key component of our RT program was the inclusion of two exercises targeting the spinal erectors: the hex bar deadlift and the lumbar extension on the Roman chair. The hex bar deadlift activates the spinal erectors for spinal stabilization, while the gluteus maximus serves as the primary hip extensor (Andersen et al., 2018; Escamilla et al., 2002). A systematic review suggests that incorporating deadlifts in NSCLBP training programs provides benefits for reducing functional disability (Fischer et al., 2021).

The lumbar extension exercise on the Roman chair, performed with pelvic stabilization, specifically targets the spinal erectors, promoting adaptations in lumbar extensor strength (Steele et al., 2015). Therefore, the positive effects observed in our study likely result from this specific combination of exercises, differing from previous studies that focused more on abdominal strengthening (Kell et al., 2011; Kell & Asmundson, 2009).

Our study found a 36.7% increase in maximum strength in participants with NSCLBP, assessed using a maximum voluntary isometric contraction test (MVIC). These results align with findings from previous studies that reported increased maximum strength in individuals with CLBP (Kell & Asmundson, 2009; Steele et al., 2013). However, earlier studies primarily employed single-joint strength tests. For instance, Graves et al. (1990) measured lumbar extension strength, while Kell and Asmundson (2009) assessed knee extension and knee flexion strength, and Verbrugghe et al. (2020) evaluated lumbar flexion and extension torque. Therefore, we believe that our multi-joint MVIC test provides a more comprehensive assessment of maximum strength.

The “Sorensen Test”, introduced in 1984, is widely used to assess isometric endurance of the trunk extensor muscles and has been shown to predict low back pain risk in men. Individuals without low back pain typically exhibit higher endurance times than those with CLBP (198 vs. 163 seconds) (Biering-Sorensen, 1984). Participants in our study demonstrated a 56.6% increase in endurance time (35.3 ± 26.8 to 55.6 ± 35.8 seconds). Despite this improvement, their final endurance time (55.6 ± 35.8 seconds) remains considerably lower than the 198-second benchmark for pain-free individuals (Demoulin et al., 2006). Thus, we recommend that individuals with NSCLBP continue resistance training beyond our intervention period.

In a 12-week resistance training study, Farragher et al. (2024) reported: a) 47% reduction in pain (5.1 ± 1.8 to 2.7 ± 2.2), b) 57% reduction in functional disability (36.9 ± 12.7 to 15.8 ± 12.1), c) 14% reduction in lumbar spine range of motion (43.3 ± 11.1 to 37.2 ± 11.0), and d) 15% increase in lumbar extension torque (130.7 ± 64.5 to 155.3 ± 81.5). Their protocol included lumbar extension exercises along with additional exercises (leg press, trunk flexion, or hip extension) chosen by a physiotherapist, with each exercise performed for 2 minutes or until fatigue. While their findings support a reduction in functional disability, we believe that their exercise selection strategy lacks consistency, potentially contributing to the observed reduction in lumbar spine range of motion.

A recent systematic review concluded that the effects of different resistance training protocols on pain and disability remain inconclusive, primarily due to risk of bias (Grooten et al., 2022). Given the strong methodological design of our study, we believe it makes a valuable contribution to future systematic reviews.

Conclusion

The findings of this study demonstrate that our low-intensity resistance training program for individuals with NSCLBP effectively reduces pain and functional disability. Additionally, the program enhances maximum strength, muscular endurance, and trunk mobility.

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