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RANDOMIZED TRIAL

A Randomized Controlled Trial of Limited Range of Motion Lumbar Extension Exercise in Chronic Low Back Pain

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Study Design. Randomized controlled trial.

Objective. To compare the effects of full range of motion (ROM) and limited ROM isolated lumbar extension exercise upon full ROM lumbar extension strength, ROM, perceived pain, and disability.

Summary of Background Data. Limited ROM is common in chronic low back pain as is lumbar extensor deconditioning. Limited ROM exercise is a common prescription but is yet to be empirically tested.

Methods. Males (n = 21) and females (n = 17) with nonspecific chronic low back pain were initially recruited. Participants were randomized to either a full ROM (FullROM) or limited ROM (LimROM) training group or a control group. A total of 24 participants (males: n = 14, females: n = 10) completed the study and were included in analysis. The intervention lasted 12 weeks. FullROM and LimROM groups completed isolated lumbar extension resistance training once per week, performing one set of exercise at 80% of their maximal tested functional torque to failure. FullROM group trained through a full ROM. LimROM group trained through the mid 50% of their full ROM.

Full ROM isolated lumbar extension strength, lumbar and standing ROM (Schobers test), perceived pain (visual analogue scale), and disability (Revised Oswestry Disability Index) were measured pre- and postintervention.

Results. FullROM and LimROM significantly improved in full ROM lumbar extension strength, perceived pain, and disability compared with the control group. No changes occurred in lumbar or standing ROM. No significant differences were found between either FullROM or LimROM for any outcome measure. Changes in perceived pain and disability met minimal clinically important change values for FullROM (visual analogue scale, −30.3 + 25.76 mm and Oswestry Disability Index, −18.2 + 6.63 patients) and LimROM (visual analogue scale, −16.29 + 10.97 mm and Oswestry Disability Index, −12 + 5.16 patients).

Conclusion. The results suggest that both FullROM and LimROM are equally effective in increasing full ROM lumbar extension strength and producing clinically meaningful improvement in perceived pain and disability.

Key words: isolated lumbar extension, MedX, lumbar extension machine, resistance training, strength training, lumbar extensor deconditioning, rehabilitation.

Level of Evidence: 2

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Chronic low back pain (CLBP) is one of the most prevalent medical disorders in today's societies.[1–4] It presents a cost of billions worldwide (≈UK £5 billion to £10 billion and[5] ≈US $100 billion to $200 billion[6]), including extensive direct healthcare costs[5–7] and greater indirect costs (≈84%–94% of total costs) through work and production losses (≈50 million to 149 million work-days lost[8,9]). CLBP is acknowledged as a multifactorial condition,[10,11] deconditioning of the lumbar extensor musculature is a consistently associated factor.[12–17] In addition, limited lumbar range of motion (ROM) is often associated with CLBP.[14,18–20] As such, some suggest limiting ROM during rehabilitation using lumbar extension resistance exercises.[21,22]

Exercise controlling ROM and isolating the lumbar extensors through pelvic stabilization is effective at improving lumbar extension strength, pain, and disability in CLBP participants.[14,23–26] Research, however, has focused upon full ROM exercise. Early research with asymptomatic participants found that limited ROM isolated lumbar extension training using a 36° ROM was sufficient for significant gains in strength through a 72° ROM.[21] Other exercises and joint movements, isolated and compound, have also been examined. Graves *et al*[27] reported that in isolated knee extension,

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limited ROM training significantly increases strength throughout the full ROM. Significant increases in full ROM strength for the bench press have also been reported.[28,29] Recent reports, however, show that, although muscle thickness increases similarly from full and limited ROM elbow flexion, full ROM training may produce significantly greater full ROM strength gains.[30]

Collectively, however, research suggests that limited ROM training can produce improvement in strength across the untrained ROM. In addition, functional status and pain in CLBP improve to a significantly greater degree with exercise following participant directional preference (*i.e.*, avoiding full flexion or full extension[31]). Avoiding painful positions during exercise may also affect adherence in CLBP participants. Long *et al*[32] reported that one-third of oppositely matched and nondirectional preference participants withdrew from rehabilitation, whereas no dropouts occurred in the directionally matched. This was perhaps due to participants following directional preference experiencing less pain during exercise when avoiding extremes of their ROM.[33]

Limited ROM lumbar extension exercise may, therefore, have merit for CLBP rehabilitation by improving full ROM strength as well as pain and disability. More research into limited ROM lumbar extension exercise in symptomatic populations is required to determine whether limited ROM training is effective in producing improvements in full ROM lumbar extension strength, pain, and disability. Thus, the purpose of this study was to test the hypothesis that both limited ROM and full ROM training will be equally effective in improving lumbar extension strength through a full ROM in addition to improving pain and disability.

MATERIALS AND METHODS

Study Design

A randomized controlled trial design was adopted with 2 experimental groups and a control group.[34] The study was approved by the NHS National Research Ethics Service, Southampton and South West Hampshire Research Ethics Committee B (REC Reference: 11/H0504/9), and the Centre for Health, Exercise and Sport Science ethics committee at Southampton Solent University, and was conducted within the Sport Science Laboratories at Southampton Solent University.

Participants

A total of 38 participants (males: n = 21, females: n = 17) were recruited through posters, group e-mail, word of mouth from Southampton Solent University, and advertisement in a local private chiropractors practice.

Power analysis of previous research with CLBP participants[35] was conducted to determine participant numbers (n) using a treatment effect size, calculated using Cohen's d[36] of 1.48 for the MedX lumbar extension. Participant numbers were calculated using equations from Whitley and Ball.[37] These calculations (Figure 1) showed that each group required 7 to meet the required power of 0.8 at an α value of $P \leq 0.05$.

$$ES = \frac{107.18^{*} - 162.57^{\dagger}}{37.28^{\ddagger}}$$

$$ES = 1.48$$

$$n = \frac{2}{1.48^2} \times 7.9$$

$$n = 7.2$$

Figure 1. Power analysis to determine participant numbers. *Mean pretest training group. †Mean post-test training group. ‡Control group standard deviation. ES indicates effect size. Data extracted from Choi *et al*.[35]

Figure 2 shows that after initial dropouts, 31 participants were randomized using an online randomization program (Research Randomizer *vs*. 3.0) to a full ROM training group (FullROM; n = 12), a limited ROM training group (training using the mid 50% of their ROM; LimROM; n = 10), or a control group (n = 9) who did not train. Throughout the study, participants continued with any current treatments or training they were receiving including medication per recommendation from the reviewing ethics committees. Participants were, however, instructed to avoid beginning any other resistance training exercises designed to address the lower back. Figure 2 also details participant attrition during the trial. Inclusion criteria were as follows: participants who experienced nonspecific low back pain having lasted longer than 12 weeks[38] and had no medical condition contraindicating resistance training. Exclusion criteria were any medical condition for which movement therapy might be contraindicated. These included acute (not reoccurring) low back injury occurring within the last 12 weeks, pregnancy, evidence of sciatic nerve root compression (sciatica), leg pain radiating to below the knee, paresthesia (tingling or numbness), current tension sign, lower limb motor deficit, current disc herniation, previous vertebral fractures, or other major structural abnormalities. All participants were cleared to exercise by either their general practitioner or a chiropractor in the research group and provided written informed consent.

Equipment

Stature was measured using a stadiometer (Holtan Ltd; Crymych, Dyfed, UK), body mass was measured using scales (SECA, Birmingham, UK), and body mass index was calculated. Isometric strength testing, ROM, and training were performed using the MedX Lumbar Extension Machine (MEDX; MedX, Ocala, FL; Figure 3). The MEDX has been shown reliable in assessing isometric strength at repeated angles in asymptomatic (r = 0.81–0.97[39]) and symptomatic participants (r = 0.57–0.93[40]) and is valid in measurement.[41,42] Standing ROM was also measured using the modified Schober's test in both flexion[43] (SchFlex) and extension[44] (SchExt). Pain was measured using a 100-mm visual analogue scale[45] (VAS), and

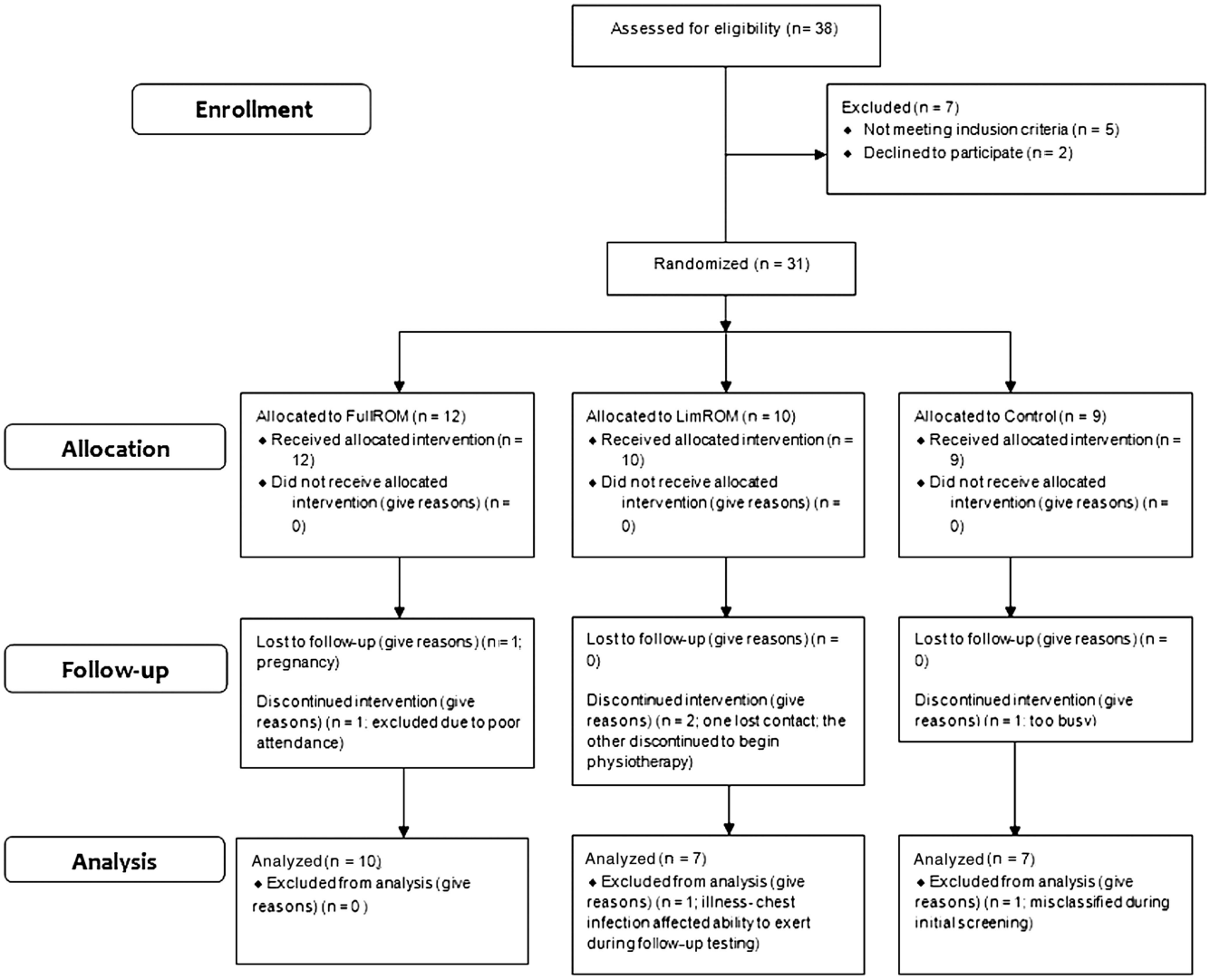

Figure 2. CONSORT flow diagram to illustrate participant numbers for enrollment, allocation, follow-up, and analysis stages.

disability was measured using the revised Oswestry Disability Index[46] (ODI).

Participant Testing

Isometric lumbar extension strength was tested twice on separate days (at least 72 hr apart to avoid residual fatigue or soreness) before and after the intervention. Each test using the MEDX involved maximal voluntary isometric contractions at various angles through the participant's full ROM. Details of the full-test protocol using the MEDX and its restraint mechanisms have been documented elsewhere.[39] During the first and second to last visit to the laboratory, participants were required to complete the VAS, the ODI, and SchFlex and SchExt.

Participant Training

Training was conducted at a frequency of once per week for a period of 12 weeks. This frequency of training has been shown to improve lumbar extension strength significantly and was chosen over more frequent training because of potential for overtraining when the lumbar extensor muscles are isolated.[47] Also, a second weekly training session offers no further improvements in symptomatic participants.[26] Twelve weeks was the chosen duration, as Carpenter *et al*[48] have demonstrated that strength improvement from this training occurs largely within the first 12 weeks. Both groups performed 1 set of variable resistance lumbar extension exercise. The FullROM group used their full ROM, whereas the LimROM group used only the mid 50% of their individual ROM (Figure 3). Resistance load was 80% of maximum recorded tested functional torque during maximal isometric testing for both groups and repetitions were performed until volitional concentric failure. Repetitions were performed taking at least 2 seconds to complete the concentric phase, holding for 1 second in full extension, and taking at least 4 seconds for the eccentric phase. Resistance load was increased by 5% in the next session once the participant was able to continue exercise for more than 105 seconds using his or her current load before achieving failure.

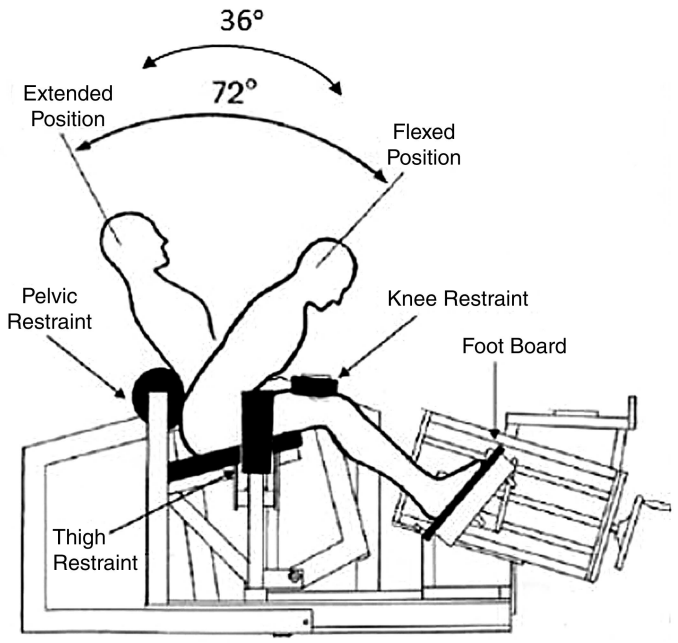

Figure 3. MEDX schematic demonstrating the restraint system and adapted here to give an example of limited range of motion using the mid 50% of a participant's individual full range of motion—in this case, 72°. Adapted and reprinted with permission from MedX Corporation.

Data Analysis

Eligibility for follow-up assessment required participants to have completed 75% of the training program within the 12-week period. A total of 24 participants' (FullROM, n = 10; LimROM, n = 7; control, n = 7) data were available for analysis. Because of individual differences between participants for lumbar ROM and subsequent determination of 50% ROM, lumbar extension strength data were broken into quartiles (Q1 and Q4 corresponding to full extension and flexion, respectively) for analysis, with the full ROM group having trained throughout every quartile (Q1, Q2, Q3, and Q4) and the limROM group having trained only through the middle 2 quartiles (Q2 and Q3). As lumbar extension strength across the ROM regresses linearly from flexion to extension,[39] the use of quartiles to encompass averaged angles was justified. In addition, although lumbar extension strength differs at different angles in accordance with the linear regression, and also relative changes after an intervention differ from flexion to extension, the change in absolute values is consistently similar regardless of test angle.[14,20,21,23,24,26,35,47] Thus, absolute change in lumbar extension strength for each quartile was compared between groups. Mauchly's test for sphericity was used to determine equality of variance between groups at $P > 0.05$. Data with assumed sphericity were subjected to 1-way analysis of variance (ANOVA). Significant results from ANOVA were further subjected to Tukey *post hoc* tests. In addition, pain and disability were compared with consensus standards for minimal clinically important change[49] (MCIC). Ostelo *et al*[49] proposed the MCIC for VAS as 15 mm and for ODI of 10 points. Pearson correlation was also conducted between change in lumbar extension strength and change in VAS and ODI. Statistical analysis was performed using SPSS (version 20; IBM, Portsmouth, Hampshire, UK) and $P \leq 0.05$ set as the limit for statistical significance.

RESULTS

Participants

Participant demographics are shown in Table 1. ANOVA revealed no significant differences between participant groups. No significant differences existed between participant groups for any baseline measurements either. Attendance between training groups for lumbar extension training sessions also did not significantly differ.

Lumbar Extension Strength

Figure 4 shows pre- and post–lumbar extension strength plotted by quartile across the ROM. ANOVA revealed a significant between group effect for change in lumbar extension strength at Q1 ($F_{2,21} = 5.074$, $P = 0.016$), Q2 ($F_{2,21} = 5.976$, $P = 0.009$), Q3 ($F_{2,21} = 7.214$, $P = 0.004$), and Q4 ($F_{2,21} = 5.033$, $P = 0.016$). Multiple comparisons using *post hoc* Tukey revealed no significant differences between FullROM and LimROM groups. FullROM increased significantly compared with control at Q1 ($P = 0.016$), Q2 ($P = 0.008$), Q3 ($P = 0.003$), and Q4 ($P = 0.024$). LimROM increased significantly when compared with control at Q4 ($P = 0.034$). LimROM approached significance when compared with control at Q1 ($P = 0.059$), Q2 ($P = 0.060$), and Q3 ($P = 0.051$).

Lumbar and Standing ROM

Absolute changes in both lumbar and standing ROM are shown in Table 2. ANOVA found no significant effects for lumbar ROM, SchFlex, and SchExt.

Oswestry Disability Index and VAS

Absolute changes in VAS and ODI are shown in Table 3. ANOVA revealed a significant between group effect for change in VAS ($F_{2,21)} = 8.263$, $P = 0.002$) and ODI ($F_{2,21} = 12.586$, $P < 0.001$). Multiple comparisons using *post hoc* Tukey revealed no significant differences between FullROM and LimROM groups for change in either VAS or ODI. FullROM decreased scores for VAS significantly compared with control ($P = 0.002$). Change in VAS for LimROM approached significance when compared with control ($P = 0.058$). FullROM and LimROM both decreased scores for ODI significantly compared with control ($P < 0.001$ and $P = 0.023$, respectively). Changes in VAS achieved the MCIC for FullROM (−30.3 + 25.76) and LimROM (−16.29+10.97) groups. MCIC was also achieved for changes in ODI for FullROM (−18.2 + 6.63) and LimROM (−12 + 5.16). The control group did not achieve MCIC values for either VAS (7.29 + 24.55) or ODI (−1.71 + 7.95).

Pearson correlation revealed significant moderate correlations between change in lumbar extension strength and

TABLE 1. Participant Baseline Demographic Characteristics

	FullROM (n = 10)	LimROM (n = 7)	Control (n = 7)	*P*
Age (yr)	46 ± 12.36	41.86 ± 17.45	41.7 ± 15.1	NS
Stature (cm)	173 ± 8	174 ± 0.08	180 ± 8	NS
Body mass (kg)	75.79 ± 14.31	79 ± 14.38	85.48 ± 18.26	NS
BMI (kg/m^2)	25.2 ± 3.15	25.85 ± 2.86	25.94 ± 4.41	NS
Symptom duration (yr)	12.99 ± 12.03	14 ± 10.86	11.85 ± 10.59	NS
Lumbar extension strength (N·m)				
Q1	116.34 ± 35.48	153.03 ± 84.60	141.3 + 52.67	NS
Q2	158.11 ± 66.74	197.69 ± 76.79	194.11 ± 58.97	NS
Q3	189.09 ± 89.34	235.75 ± 102.39	212.96 ± 55.79	NS
Q4	231.67 ± 91.52	265.58 ± 108.72	279.06 ± 83.70	NS
Lumbar ROM (degrees)	64.5 ± 12.1	68.57 ± 6.8	62.7 ± 6.24	NS
Schobers standing ROM (cm)				
SchFlex	21.66 ± 1.57	21.66 ± 1.00	21.31 ± 1.32	NS
SchExt	12.92 ± 0.76	13.03 ± 0.69	13.14 ± 0.59	NS
VAS (mm)	46.73 ± 25.53	41.29 ± 22.92	19.2 ± 15.51	NS
ODI (points)	36.18 ± 11.12	26.86 ± 13.56	26.2 ± 7.27	NS
Attendance (%)	86.67 ± 8.96	80.95 ± 12.47	NA	NS

Results are mean ± SD.

BMI indicates body mass index; NS, not significant; ROM, range of motion; VAS, visual analogue scale; ODI, Oswestry Disability Index; NA, not available.

VAS for Q1 ($r = -0.484$, $P = 0.017$), Q2 ($r = -0.595$, $P = 0.002$), Q3 ($r = -0.651$, $P = 0.001$), and Q4 ($r = -0.464$, $P = 0.022$). Significant moderate correlations were shown for Q2 ($r = -0.453$, $P = 0.026$) and Q3 ($r = -0.522$, $P = 0.009$) between change in lumbar extension strength and change in ODI. Q4 approached significance ($r = -0.390$, $P = 0.060$). No significant correlation was seen for Q1 ($r = -0.261$, $P = 0.219$).

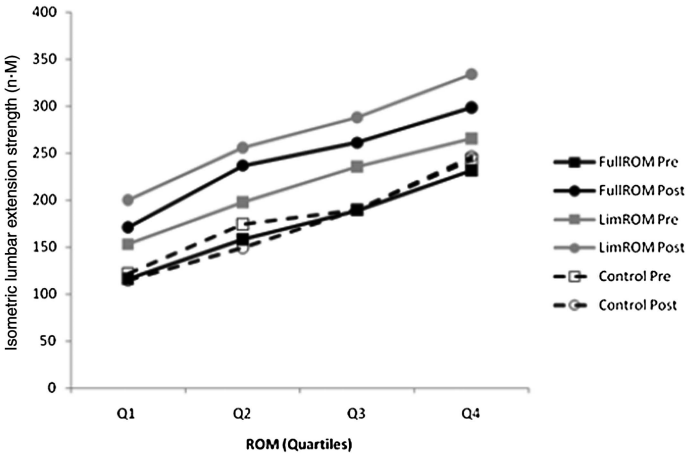

Figure 4. Pre– and post–mean isometric lumbar extension strength curves plotted by quartile across the range of motion.

DISCUSSION

This study is first to demonstrate that both full ROM and limited ROM lumbar extension exercises are equally effective in improving lumbar extension strength, pain, and disability in CLBP participants. The lack of statistically significant differences between the FullROM and LimROM training groups for increases in lumbar extension strength (~22% to ~54%) at all quarters of the ROM supports the theory that limited ROM exercise does indeed increase strength throughout the full ROM. These increases are also comparable with those obtained through full ROM exercise confirming our hypothesis. These results in CLBP participants are in accordance

TABLE 2. Change in Lumbar and Standing ROM

	FullROM	LimROM	Control
Lumbar ROM (degrees)	5.1 ± 6.01	0.43 ± 1.13	1.8 ± 2.09
Schobers standing ROM (cm)			
SchFlex	0.18 ± 1.29	0.05 ± 0.94	−0.22 ± 0.62
SchExt	−0.15 ± 0.65	0.17 ± 0.49	−0.05 ± 0.32

Results are mean ± SD.

ROM indicates range of motion.

TABLE 3. Change in VAS and ODI

	FullROM	LimROM	Control
VAS (mm)*	−30.3 ± 25.76†	−16.29 ± 10.97†	6.71 ± 14.89
ODI (points)*	−18.2 ± 6.63†	−12 ± 5.16†	−3 ± 6.87

Results are mean ± SD.

**P < 0.05 between groups comparison with analysis of variance.*

†P < 0.05 between training group (FullROM/LimROM) and control.

ROM indicates range of motion; VAS indicates visual analogue scale; ODI, Oswestry Disability Index.

with those seen in asymptomatic participants for lumbar extension,[21] symptomatic CLBP participants,[14,23–26] and other exercises.[27,28]

Lumbar ROM showed no significant changes as a result of the intervention. Other studies have also reported no change in ROM as a result of training using the MEDX,[24,25] yet these and this study contrast with others that demonstrated a significant improvement.[14,26] A possible reason for the lack of difference in lumbar ROM in this study, however, may be the population examined. Baseline lumbar ROM in studies showing an improvement (54°–65° [in Nelson *et al*[14] and Bruce-Low *et al*[26]]) was lower than the baseline lumbar ROM of participants in this study (65°–68°) and others who have not shown an improvement (64° [in Smith *et al*[25]]). Lower baseline lumbar ROM might allow greater potential for improvement, an issue that warrants further examination in future studies.

Standing ROM also showed no significant changes as a result of the intervention. In contrast, other research has shown improvements in SchFlex as a result of training using the MEDX in CLBP participants.[26] Reasons for this discrepancy may be similar to those offered for the lack of difference in lumbar ROM measured using the MEDX. Participants in the study by Bruce-Low *et al*[26] had baseline SchFlex ranging from approximately 14 cm to 19 cm, whereas participants in this study had baseline measurements of approximately 21 cm. Again, there may have been less potential for an improvement. An alternative explanation may be due to the inherent sources of error in Schobers tests. Although a widely used method,[50,51] unavoidable sources of error exist, the most prominent being palpation and identification of anatomical landmarks.[51–54] Lumbar ROM measured using the MEDX is instead considered a more valid technique.[55]

Further in line with our hypothesis, both FullROM and LimROM demonstrated significant reductions in pain and disability compared with the control group. No difference was observed between the two training groups. Previous research shows that the MEDX produces significant and meaningful reductions in pain and disability in CLBP participants.[14,23–26] These studies have, however, all used full ROM exercise. The results of this study confirm that full ROM lumbar extension exercise is not essential for significant improvement of pain or disability.

The changes demonstrated in VAS and ODI for both FullROM and LimROM achieved the consensus MCICs,[49] whereas the control group did not. Thus, both full and limited ROM lumbar extension exercises can produce clinically meaningful improvements in both pain and disability in symptomatic CLBP participants.

Recently, it has been questioned whether reductions in pain and disability are related to improvements in muscular performance.[56] However, research using the MEDX was not considered in this review.[57,58] It may be that the studies considered in review did not use specific enough exercises to address the lumbar extensors. Furthermore, an issue raised in this review[56] was that many have not reported correlations between these outcomes. As such, we considered this within this study and report significant moderate correlations between change in lumbar extension strength and pain ($r = -0.488$ to -0.668) and change in lumbar extension strength and disability ($r = -0.414$ to -0.539). This indicates that the greater the improvement in lumbar extension strength, the greater the reduction in pain and disability. This may be due to the specificity of the exercise possible using the MEDX, but this requires clarification.

The results of this study suggest that limited ROM lumbar extension exercise is as effective as full ROM lumbar extension exercise in improving lumbar extension strength throughout a full ROM, in addition to reducing pain and disability. Thus, recommendations to prescribe limited ROM exercise for those with CLBP[21,22] are now supported by empirical evidence. There also exists potentially further applied benefit of these recommendations based upon other findings regarding ROM and pain. Movement to full extension or flexion has significant impact upon pain experienced in symptomatic participants,[33] and avoiding painful positions during exercise can positively affect outcome and adherence.[31,32] No significant differences were seen between training groups for attendance (FullROM 86.67 + 8.96% *vs*. LimROM 80.95 + 12.47%) in this study. Long *et al*[32] examined attendance using a 2-week intervention length common to the type of intervention used in their study. This study was 12 weeks in length and showed little in the way of participant attrition once participants had begun training (Figure 2). Perhaps after a longer intervention period, any differences may become apparent between the two groups (FullROM and LimROM). Alternatively, our results suggest that the MEDX is perhaps an approach that maintains participant adherence, offering an avenue for future research.

A concern that exercise may cause reinjury always exists. In this respect, limited ROM lumbar extension exercise may be safer for CLBP participants, as cumulative fatigue (such as experienced during a set of fatiguing exercise) results in greater spinal flexing[59–62] and moves very close to the margin of safety for the intervertebral disc.[61] However, this study was not of sufficient design and size to determine this and, as with other points made in this discussion, this is an area that needs clarifying through further research.

Although our power analysis revealed that 7 participants per group would be sufficient, and thus this study should be

considered as adequately powered, future work should seek to replicate this design attempting to increase participant numbers to test whether these results are replicable.

To conclude, the results of this study demonstrated that both full ROM and limited ROM lumbar extension exercises could improve lumbar extension strength throughout a full ROM in addition to producing reductions in both pain and disability. From a clinical perspective, these improvements achieve MCIC for pain and disability and so both approaches could be deemed as appropriate to recommend for CLBP participants.

➢ Key Points

- ❑ Full ROM and limited ROM lumbar extension exercises can improve lumbar extension strength throughout a full ROM.
- ❑ Full ROM and limited ROM lumbar extension exercises also produce significant and clinically meaningful improvements in pain and disability.
- ❑ Recommendations to limit ROM during rehabilitative exercise seem justified in this population and thus this may be of benefit to clinicians dealing with participants with limited ROM or end ROM pain.

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