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The effect of lumbar extension training with and without pelvic stabilization on lumbar strength and low back pain[1]

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Abstract. *Introduction:* A dynamometer employing a stabilization procedure (lumbar extension machine, MedX, Ocala, FL) is effective in improving strength and reducing symptoms of low back pain (LBP), and researchers have hypothesized that this effectiveness is due to the pelvic stabilization. However, effects of the dynamometer with and without pelvic stabilization on LBP have not been compared: This was the aim of the present study.
Methods: Forty-two chronic LBP patients were randomly assigned to a lumbar extension training with pelvic stabilization group (STAB; $n = 15$), a lumbar extension without pelvic stabilization group (NO-STAB; $n = 15$) and a control group ($n = 12$). STAB and NO-STAB participants completed one weekly session of dynamic variable resistance exercise (one set of 8–12 repetitions to fatigue) on the lumbar extension machine (with or without pelvic stabilization) for 12 weeks. Pre- and post-test measures of self-reported LBP (101-point visual analog scale; pre-test mean of 25), related disability (Oswestry disability index; pre-test mean of 34) and lumbar strength were taken.
Results: After the exercise program, the STAB group increased significantly in lumbar strength at all joint angles, and decreased significantly in visual analogue and Oswestry scores. However, there were no significant changes in these variables in the NO-STAB and control groups.
Discussion: Isolated lumbar extension exercise is very effective in reducing LBP in chronic patients. However, when the pelvis is not stabilized, otherwise identical exercises appear ineffective in reducing LBP.

Keywords: Lumbar region, exercise therapy, weight lifting

1. Introduction

Weakness of the muscles that extend the lumbar spine is a risk factor for low back pain [19,20,26], and therefore resistance training is often prescribed for prevention and treatment of LBP. A dynamometer that enables isolation of the lumbar muscles through stabilizing the pelvis (MedX lumbar extension machine, MedX, Orlando, FL) is effective in enhancing lumbar extension strength. For example, Graves et al. [10], Carpenter et al. [1], Pollock et al. [23] and Deutsch [4] have shown increases in isometric strength of over 100% in the fully flexed position from one set of 8–12 repetitions of lumbar extension exercise performed to volitional fatigue once per week for 10–12 weeks. Interestingly, more frequent training (2 or 3 times per week) does not produce better results [10].

Perhaps more importantly, such a training protocol can also significantly reduce LBP. For example, Holmes et al. [13] and Dolan et al. [5] found reductions in pain following regular lumbar extension exercise in chronic

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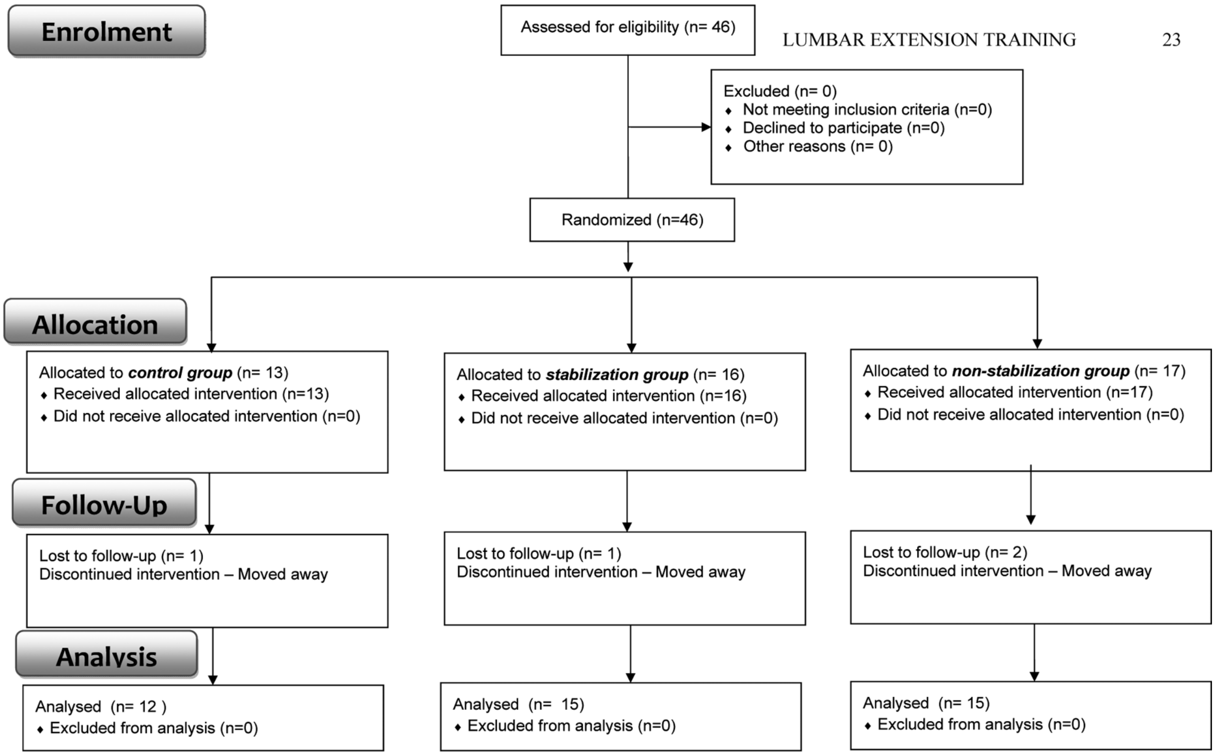


Fig. 1. CONSORT Flow Diagram to illustrate participant recruitment and retention.

patients. Choi et al. [2] administered a 12-week post-operative lumbar extension training program to herniated disc patients. Following the training, patients decreased their self-reported pain, and 87% of exercising participants returned to work compared to only 24% of controls. Several other studies have produced similar findings (for a review, see Smith, Bruce-Low and Bissell [25]). It has been hypothesized that the positive results from such exercise programs are due to the pelvic stabilization that this apparatus provides [25].

However, not all research agrees that stabilization is required [28]; there is still some controversy in this regard. However, the effects of lumbar extension exercise with and without pelvic stabilization on LBP have not yet been directly compared whilst controlling confounding variables such as other differences in machine design. To determine whether pelvic stabilization is necessary for optimal improvements in strength and decreases in LBP, a comparison of machines that are identical apart from the pelvic restraint mechanism is necessary.

This was the aim of the present study, a randomized controlled trial. We hypothesized that training on the lumbar extension machine with the pelvic restraint in place would significantly enhance lumbar extension strength and reduce LBP, and that training on the machine without the pelvic restraint would not produce improvements in these variables.

2. Methods

2.1. Participants

Following approval by the university's ethics committee, 42 chronic LBP patients (Mean age = 42.93 years, SD = 10.80) attending a private chartered physiotherapist took part in the study (please refer to the CONSORT flow diagram for details of participant numbers – Fig. 1). All participants were provided with a participant information sheet and given adequate time to decide if they wished to be involved with the study. On deciding to participate within the study, written informed consent was obtained. To be eligible, participants had to have suffered from LBP for at least six months prior to the study but have no medical condition for which exercise is contraindicated. Participants completed a health screening form, and those reporting any of the following conditions, symptoms and/or history were excluded from participation: Malignancy or

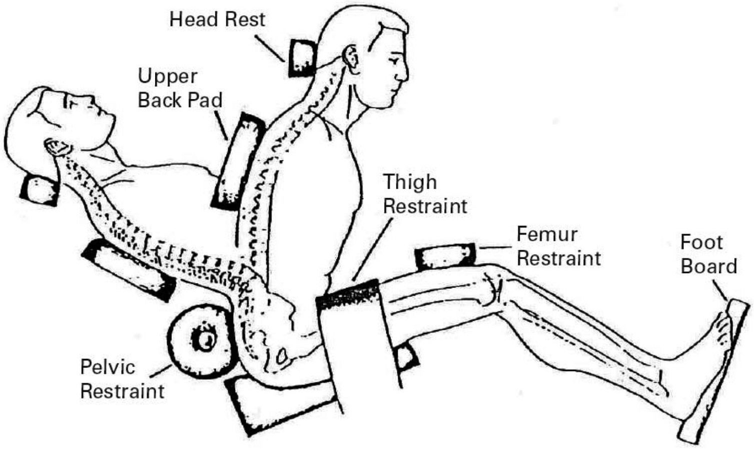


Fig. 2. Restraint system used to isolate pelvic movement and an illustration of the full ROM of 72° of lumbar spine movement (reproduced with permission from MedX Corporation, Ocala, FL).

underlying disease (defined as a systemic problem that affects a number of organs, tissues or affects the body as a whole which would prevent them from partaking in strenuous physical exercise, e.g., significant cardiovascular disease, high blood pressure, poorly controlled diabetes and osteoporosis), disc herniation, osteoporosis, neurologic or sciatic nerve root compression, vertebral fractures, major structural abnormality of the spine, tumor of the spine, problems passing water or solids, inflammatory arthritis and pregnancy.

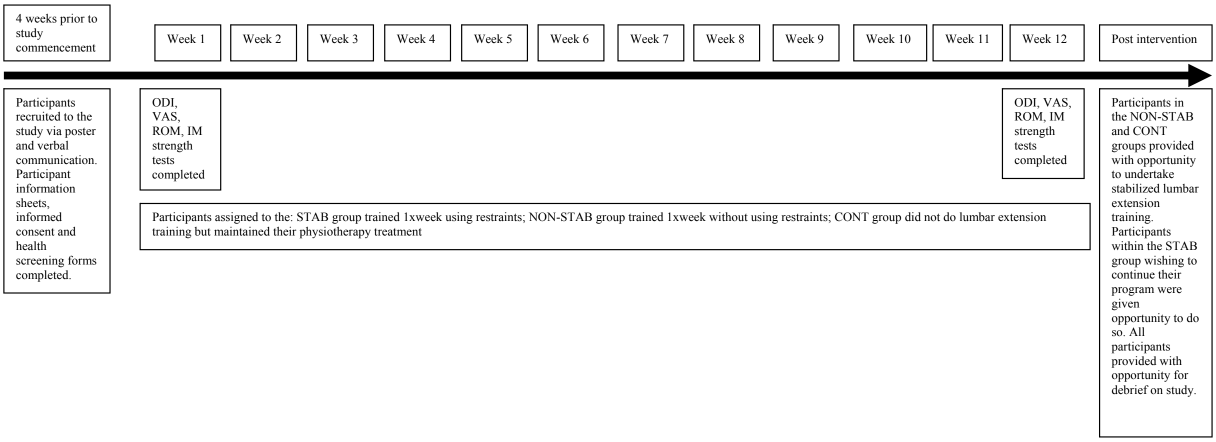
All participants were physically screened (by a Chartered physiotherapist with a musculoskeletal and spinal special interest) for significant disc pathology which would exclude their participation. Some of our participants had been screened previously by their Doctor or Consultant to exclude major disc problems via Magnetic Resonance imaging. None had been screened by provocative discography. Participants were excluded if the disc problem was significant with significant (and often causing) neural involvement. The examination consisted of a subjective questioning and a physical examination to assess for more severe/significant disc herniation with questioning and testing for nerve root compression, bladder and bowel symptoms, radicular symptoms, sensory and motor abnormalities, pain distribution and type, and adverse mechanical neural tension.

2.2. *Equipment*

2.2.1. *Lumbar Extension Machine* (*MedX, Ocala, FL*)

All strength tests and strength training sessions were conducted by members of the research team who were fully certified by the manufacturer to operate the lumbar extension machine, which can be used to perform isometric strength tests throughout the full lumbar range of motion (ROM) at 6° intervals. The machine can also measure lumbar extension ROM in a seated position, and can also be used for dynamic, variable resistance lumbar extension training. The machine incorporates a pelvic restraint mechanism that works as follows (please also see Fig. 2): Participants are seated in the machine in an upright position with their thighs at an angle of 15° to the seat. A restraining belt is secured over the anterior part of the upper thigh and femur restraint pads are positioned over the thigh just superior to the knees. These restraints prevent unwanted vertical movement of the pelvis or thighs. A force is then exerted along the legs by cranking forward a footrest, which pushes the pelvis against a pelvic restraint that is free to rotate on its axis. The tester can then check for pelvic movement by checking for rotation of the pelvic restraint and if any is observed the restraints are then tightened until there is no further rotation.

The machine also incorporates a counterweighting procedure to counterbalance the effect of gravity acting on the upper body. This involves locking the counterweight in place at the neutral, upright position and then adjusting it whilst the participant rests at 0° of lumbar flexion. When ready to test, the movement arm on the machine is locked at the relevant joint angle (measured using the machine's goniometer) and the participant is requested to build up to maximal tension over 2–3 s and to maintain the contraction for another 1 s. The torque produced is measured by a load cell attached to the movement arm. The validity and reli-



Participants recruited to the study via poster and verbal communication. Participant information sheets, informed consent and health screening forms completed.

Participants assigned to the: STAB group trained 1xweek using restraints; NON-STAB group trained 1xweek without using restraints; CONT group did not do lumbar extension training but maintained their physiotherapy treatment

Participants in the NON-STAB and CONT groups provided with opportunity to undertake stabilized lumbar extension training. Participants within the STAB group wishing to continue their program were given opportunity to do so. All participants provided with opportunity for debrief on study.

Fig. 3. Intervention timeline.

ability of both the restraint and counterweighting procedures are well-established [9,10,14] and the torque measurements show very high test-retest reliability at all angles ($r = 0.94$–0.98 [22]).

2.2.2. *Oswestry Disability Index* (*ODI [6]*)

This questionnaire gives a subjective percentage score of level of disability in activities of daily living resulting from low back pain. It examines perceived level of disability in 10 everyday activities of daily living, namely pain intensity, personal care, lifting, walking, sitting, standing, sleeping, sex life, social life and travelling. It has a high degree of sensitivity as a measure of change following treatment [7], high test-retest reliability (intraclass correlation of 0.94 [12]) and a high correlation with pain intensity [11]. Participants were given explicit verbal instruction on how to complete the ODI and provided with adequate time to ask questions prior to completing it.

2.2.3. *Visual Analog Scale* (*VAS*)

The VAS used in this study consisted of a 10 cm line anchored by two extremes of pain. Participants were asked to mark the line at the point representing their perceived pain intensity and the pain was scored by measuring the distance in millimeters from the ‘no pain’ end to the mark made by the participant. Thus, the maximum pain score was 100. Participants were given explicit verbal instruction on how to complete the VAS with appropriate and specific anchoring statements. In addition, participants were provided with adequate time to ask questions prior to completing it. This method is reliable, with no differences found when administered by different testers [21], and possesses high predictive validity [15]. In order to investigate if the changes in VAS scores were meaningful the minimal clinical important change (MCIC) was calculated from the mean differences between the post and the pre intervention VAS scores [18]. The MCIC of between 15 and 35 is typically observed in patients with chronic low back pain [17,18].

2.3. *Procedure*

2.3.1. *Group allocation*

Participants were randomly allocated to one of three groups: Lumbar extension training with pelvic stabilization (STAB), lumbar extension training without stabilization (NO-STAB), and control. Control participants continued their normal course of LBP treatment with the same physiotherapist, which involved mobilizations, McKenzie protocol, muscle imbalance protocol, home exercises and postural advice/ergonomics over the 12 week intervention. Participants within the control group were aware of the study objectives thus, following completion of the study, all participants in the NO-STAB and control groups were offered the chance to receive the lumbar extension training with pelvic stabilization (please refer to Fig. 3 for intervention time line).

2.3.2. *Pre- and post-tests*

Prior to lumbar strength tests, all participants completed the ODI and the VAS. Participants then completed two isometric lumbar extension strength tests administered one week apart. As previous research [23] has shown it is important that participants are familiar with the testing procedure to produce reliable results, the initial testing session was designated as a famil-

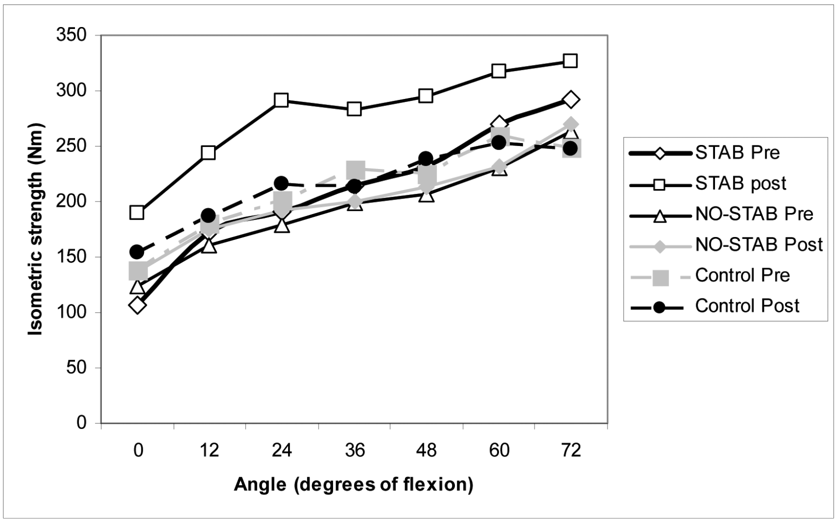


Fig. 4. Pre- and post-test mean isometric torque at each joint angle.

iarization session. The second test was used to obtain pre-test measures of lumbar extension strength.

In accordance with standard procedure on this machine, isometric lumbar extension torque was measured at intervals of 12° from 0° to 72° of lumbar flexion. Prior to testing, the restraining and counterweighting procedures were carried out as described above, and lumbar ROM in the machine was measured using the machine's goniometer. The headrest in the machine was adjusted so it sat at the base of the occipital bone, for comfort and standardization, and the arm position of the participants was standardized by asking them to lightly grasp the handlebars that extend from the movement arm.

Following these procedures, strength tests were conducted at each angle using the procedure described above, with approximately 10s rest between the tests. Any tests in which the participant felt he or she did not give a maximal effort were repeated. Following completion of the training protocols described in the following section, the strength tests, Oswestry and VAS were repeated.

2.3.3. Training

Participants in the STAB and NO-STAB groups performed one lumbar extension training session per week for 12 weeks. In all cases this involved one set of ∼8–12 repetitions through the participant's full ROM on the lumbar extension machine to volitional fatigue. Repetitions were performed slowly, with 2 s taken to lift the weight and 4 s taken to lower it. When participants could perform more than 12 repetitions, the weight was increased by approximately 5%. This training protocol is standard in studies using the machine, and has been found to produce optimal strength increases [10]

2.3.4. Data analysis

Maximal voluntary isometric torque was measured in foot pounds and converted to Newton meters for analysis. Descriptive statistics were calculated for all dependent variables and two way (group x test) ANOVAs were performed to examine the effects of the interventions on isometric torque, ODI and VAS scores, with Tukey HSD tests when appropriate. The alpha level was set at $P < 0.05$. The sample size has been determined using the calculation [3] below based upon previous research [27]. The equation accounts for 7% accuracy and thus each group requires 12 participants.

$$SE = \sqrt{\frac{n \times SD^2}{n-1}}$$

$$n = 95\%\, C.I. \times SE$$

7% level of accuracy

SE = Standard Error; SD = the standard deviation of the mean strength produced by the participants in Tucci et al.'s study; C.I. = confidence interval.

3. Results

3.1. Isometric torque

Figure 4 shows the mean isometric torque at each angle of measurement. It can be seen that isometric

Table 1
Effect sizes for STAB, No-STAB and Control groups' strength increases at each joint angle

Group	0°	12°	24°	36°	48°	60°	72°
STAB	1.03	0.64	0.88	0.50	0.40	0.29	0.17
NO-STAB	0.19	0.27	0.22	0.00	0.09	0.01	0.07
CONTROL	0.18	0.07	0.15	0.15	0.11	0.05	0.00

Table 2
Mean and standard deviation pre- and post-test scores for the ODI, VAS and seated lumbar ROM

Group	ODI pre	ODI post	VAS pre	VAS post	ROM pre	ROM post
STAB	39.20 ± 14.70	27.30 ± 11.60	30.10 ± 17.20	13.40 ± 10.80	64.40 ± 9.13	66.80 ± 6.66
NO-STAB	35.70 ± 12.60	34.00 ± 12.60	28.70 ± 17.39	28.07 ± 21.82	65.00 ± 9.73	65.00 ± 9.73
CONTROL	32.70 ± 5.90	33.80 ± 6.30	26.80 ± 9.00	26.50 ± 10.20	66.50 ± 8.57	66.50 ± 8.57

Table 3
NRS scores ($\bar{x}$diff ± SD) and 95% CI for all groups

Group	$\bar{x}$ diff ± SD	95% CI
STAB	−16.7 ± 9.0	−23.2 to −10.2
NON-STAB	−0.6 ± 13.1	−7.8 to 6.6
CONTROL	−0.4 ± 3.5	−2.7 to 2.0

torque increased between pre- and post-test at each joint angle for the STAB group, with the magnitude of the increases reducing towards the fully flexed position. The group x test ANOVA for peak isometric lumbar torque revealed a significant interaction effect, F(2,39) = 15.76, $P < 0.001$. Tukey HSD tests revealed no significant between-group pre-test differences but the post-test torque produced by the STAB group was significantly greater ($P < 0.05$) than that produced by the NO-STAB and control groups. Identical interaction effects and Tukey test results (in terms of significant differences) were noted at each joint angle, with F values of 11.85 ($P < 0.001$), 8.07 ($P < 0.001$), 14.97 ($P < 0.001$), 18.75 ($P < 0.001$), 5.17 ($P < 0.001$), 11.91 ($P < 0.01$) and 4.30 ($P < 0.05$) for 0°, 12°, 24°, 36°, 48°, 60° and 72° respectively. Effect sizes can be seen for each group at each joint angle in Table 1.

Effect sizes at all angles apart from 60° and 72° for the STAB group were classified as large or medium according to Cohen [3], whereas all effects for the NO-STAB and control groups were classified as small. Percentage increases in torque for the STAB group were as follows: 78.60% (0°), 41.55% (12°), 52.45% (24°), 32.16% (36°), 26.75% (48°), 17.12% (60°) and 12.02% (72°).

3.2. Back pain, disability and ROM measures

The group x test ANOVA for ODI scores revealed a significant interaction effect, F(2,39) = 5.64, $P < 0.01$, and this was also the case for the VAS, F(2,39) = 5.59, $P < 0.01$ as shown in Table 2. In both analyses, Tukey HSD tests revealed no significant differences in the pre-test ($P < 0.05$ in all cases) but the post-test VAS and ODI scores for the STAB group were lower ($P < 0.05$) than those of the NO-STAB and control groups. Effect size calculations revealed a large effect from the STAB intervention on ODI scores ($d = 1.05$), but small effects from the NO-STAB and control interventions ($d = 0.09$ and 0.16 respectively). Table 3 shows the VAS $\bar{x}$ differences ± SD and 95% CI data between the VAS scores obtained before and after the intervention. The MCIC was obtained for the STAB group (−16.7 ± 9.0) but not for either the NON-STAB or control groups (−0.6 ± 13.1 and −0.4 ± 3.5 respectively). The STAB intervention had a moderate effect on VAS scores ($d = 0.71$), whereas the NO-STAB and control interventions had small effects ($d = 0.02$ and 0.25 respectively). The group x test ANOVA for seated lumbar ROM just failed to reach statistical significance, F(2,39) = 3.13, $P = 0.06$.

4. Discussion

The aim of this study was to compare the effects of lumbar extension training with and without pelvic stabilization in chronic LBP patients. The statistically significant improvements in lumbar extension strength at all joint angles and decreases in self-reported LBP and disability in the STAB group are in accordance with previous findings [2,5,23]. The magnitude of the improvements in our population of chronic patients, many of whom had suffered from LBP for years and even decades, compared very favourably with the effectiveness of the standard treatments these participants had received previously. They also compared very favourably with the effects of the physiotherapy treatments given to the control participants, whose self-reported LBP and disability scores did not decrease significantly during the course of the study. The changes in the STAB group VAS scores did reach the MCIC, which were consistent with other researchers [17,18], but neither the NON-STAB nor Control groups met the MCIC and it is also important to note that the effect size calculations revealed large and moderate effects on the ODI and VAS scores respectively with a relatively short intervention (i.e., 12 weeks). Given this, we think that future research is required to examine whether longer-term use of the machine will produce even better results in terms of additional strength increases and decreases in LBP, or whether the gains demonstrated begin to plateau after a certain period of time.

We have shown that lumbar extension training with pelvic stabilization can be an effective treatment for chronic LBP, and that improvements in this population will occur in a matter of weeks. Particularly noteworthy is the relatively small amount of exercise (one set of 8–12 repetitions per week) required to produce such results. Therefore, this method of therapy is very time-efficient and can easily fit in with even the busiest lifestyle.

In line with our hypothesis, lumbar extension training without pelvic stabilization did not improve lumbar strength or decrease self-reported LBP or disability. This finding concurs with that of Graves et al. [9], who found that 'low back' machines that do not stabilize the pelvis do not increase lumbar extension strength, in contrast to the lumbar extension machine. However, the present study extended the findings of Graves et al., in two important ways. Firstly, given that the machine was developed partly as a treatment for LBP, we felt it was important to compare the effects of lumbar extension training with and without pelvic stabilization in LBP patients rather than healthy participants as in the Graves et al. study. Also, given the many other differences between the lumbar extension machine and the 'low back' machines compared by Graves et al., an examination of the effects of lumbar stabilization, with all other factors constant (i.e., using the same machine), was necessary to clearly establish the necessity of this for effective lumbar extension exercise (controlling the other factors such as shape of cam, level of friction and range of motion). Our findings clearly show that pelvic stabilization is essential to exercise the lumbar muscles effectively, and that such stabilization is necessary not only to increase lumbar extension strength but also to decrease LBP and improve low back function.

Not all research is commensurate with our findings. For example, Walsworth [28] compared the use of the lumbar extension machine with the Cybex dynamic variable resistance trunk extension machine in healthy participants. Surface EMG activity was recorded from the L3-4 paraspinal region during trunk extension. Their results showed no differences in EMG activity during trunk extension on the two machines. However, the effect of the two machines on strength was not compared, and the low participant numbers in the Walsworth study ($n = 13$) suggest that the statistical power of the analysis may have been low.

Isolation therefore appears to be key to effective rehabilitation of the lumbar muscles. Without isolation of the joint movement, the overload provided by the resistance will not effectively target the lumbar muscles as the larger muscles of the buttocks and the rear of the thighs, which work together to move the pelvis in the direction of extension, will produce most of the force required to move the weight. Therefore, meaningful exercise for the lumbar muscles cannot be provided if the exercise involves these other muscles too.

The fact that it is so difficult to exercise the lumbar extensor muscles may well explain why the lumbar extensor muscles are chronically weak, even in healthy, asymptomatic participants [10,23]. If pelvic stabilization is essential to enable strengthening of the lumbar extensors, then even those who perform regular weight training may suffer from disuse atrophy of the lumbar muscles, and should include lumbar extension training in their exercise regimes to maintain low back health. This assertion is supported by a recent case study [16], which found that a participant who had had his lumbar strength measured in 1995, had lost an average of 42% of this strength when measured 10 years later, despite regularly performing heavy deadlifts, squats, bent-over rows and other weight training exercises that load the lumbar spine.

The weakness of the lumbar muscles in those beginning a program of lumbar extension exercise may also explain the very large potential for strength increases in this muscle group. The strength increases shown by participants in the STAB group (mean increase in peak torque of 78.60%) are much greater than strength increases shown in studies involving other muscle groups and a similar time frame (15% to 31% improvement; see review by Fleck and Kraemer) [8]. Therefore, as noted by Carpenter et al. [1], the large strength gains from lumbar extension training in novice participants probably reflect the initial weakness and strength potential of this muscle group. It is worth noting that, although the strength increases at all joint angles for the STAB group were statistically significant, the increases at 60° and 72° were small according to the effect size calculations. This may be because most individuals are strongest in these positions and therefore the potential for strength gains is lower than at other joint angles. It cannot be ruled out, however, that for optimal strength increases at these angles alternative lumbar extension training protocols may be required (e.g. more or less volume and/or frequency), and this possibility is worthy of further investigation.

In conclusion, pelvic stabilization during lumbar extension exercise is essential to produce meaningful results. This is true both in terms of increasing the strength of the lumbar muscles and, more importantly from a clinical point of view, reducing the intensity of LBP and associated disability. These findings have important implications for the design of LBP rehabilitation programs. Essentially, providing that exercise is not contraindicated for the specific patient, isolated lumbar extension training should be part of the treatment regimen for LBP. Such an exercise program should be preferred to the more common 'back extension' exercises that do not stabilize the pelvis, as these are unlikely to produce a chronic effect on the lumbar muscles.

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