Volume 3, Number 3, 2026 Pages 1868-1876

Bioscience Insights

ISSN: 3080-3489 (Print)
ISSN: 3080-3497 (Online)

BioSciInsights.com

EFFECT OF MOTOR CONTROL EXERCISE WITH REAL-TIME BIOFEEDBACK ON LUMBAR STABILITY AND DISABILITY IN CHRONIC LOW BACK PAIN PATIENTS

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https://doi.org/10.5281/zenodo.24337690

Article Information

Article History

Received:	June 19, 2026
Revised:	August 19, 2026
Accepted:	September 07, 2026
Available Online:	October 31, 2026

Keywords:
Biofeedback, Low Back Pain, Lumbar Vertebrae, Muscle Development, Neuromuscular Junction, Postural Balance, Randomized Controlled Trial

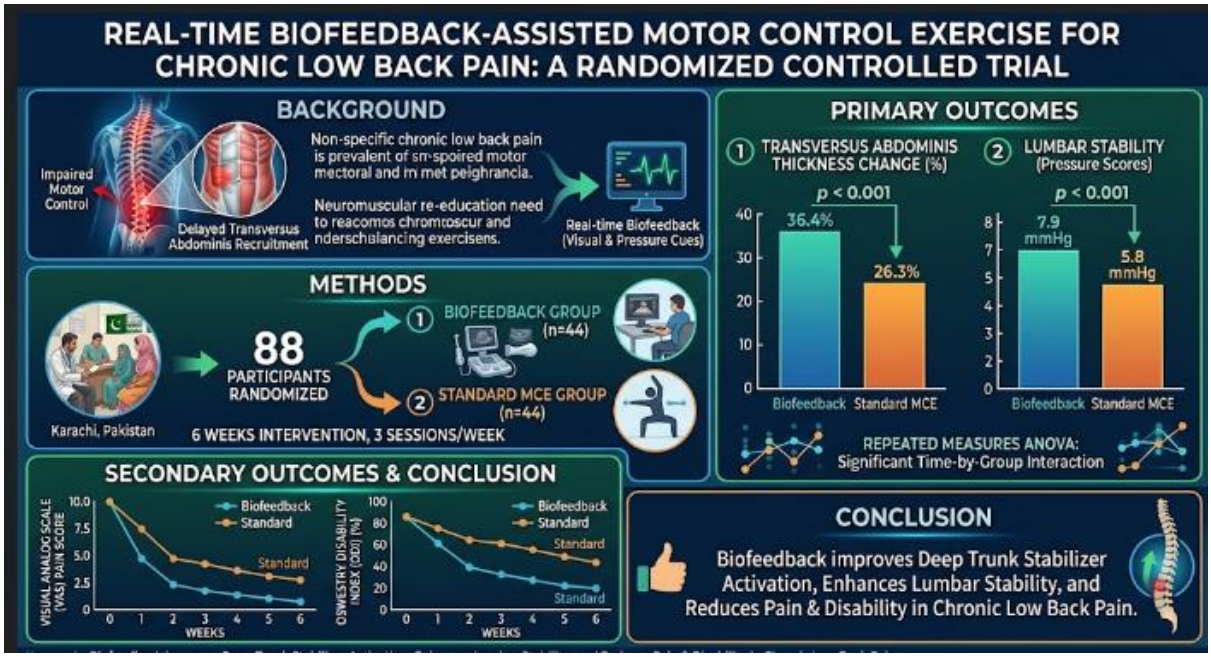
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Abstract

Background: *Chronic low back pain, the non-specific variety, is often accompanied by motor control dysfunction and delayed activation of deep, stabilising trunk muscles. Real time biofeedback can assist in neuromuscular re-education to give performance cues in visual and pressure feedback in real time while performing exercise.*
Study design: *A randomized controlled trial.Study participants: Sixty-two patients with chronic low back pain.*
A six month parallel group randomized control trial was done in Karachi, Pakistan. A total of 88 participants with chronic low back pain were randomly assigned to either the motor control exercise group given real-time pressure and ultrasound biofeedback (n=44) or the standard motor control exercise group (n=44) and received eight weeks of intervention (three sessions per week). Primary outcomes were change in thickness (%) of the transversus abdominis muscle (rehabilitative ultrasound) and lumbar stability (pressure biofeedback unit). Secondary outcomes were pain intensity (Visual Analog Scale) and functional disability (Oswestry Disability Index). The outcomes were assessed at baseline and six weeks after intervention.
Results: *82 participants finished the six week trial (41 participants per group). The intervention group showed a significantly higher increase in percent change in transversus abdominis thickness compared to control group (36.4 ± 5.2% vs 26.3 ± 4.8%, $p < 0.001$), and higher pressure stabilization score than control group (7.9 ± 1.4 mmHg vs 5.8 ± 1.3 mmHg, $p < 0.001$). Repeated*

measures ANOVA showed that there was a significant time and group interaction for the muscle thickness change ($F = 28.6$, $p < 0.001$). Significant improvements were also observed for Visual Analog Scale pain scores (2.1 ± 0.9 cm vs. 3.8 ± 1.1 cm, $p < 0.001$) and Oswestry Disability Index scores (14.2 ± 4.8% vs. 22.6 ± 5.5%, $p < 0.001$) in favor of the biofeedback group.

Conclusion: *Real time biofeedback during motor control training is a very effective method to increase deep trunk stabilizer activation and increases lumbar stability and decreases pain and disability in chronic low back pain.*



INTRODUCTION

Globally, few conditions drain workforce productivity or drive physical disability quite like chronic low back pain (1). The clinical and financial toll is massive. In fast-growing cities like Karachi, Pakistan, this problem is compounded by long hours at poorly set up desks, rapid urban sprawl, and the simple fact that specialized rehabilitation clinics remain out of reach for most people (2). Biologically, a major piece of the puzzle in non-specific chronic low back pain is how the nervous system coordinates the trunk muscles—particularly deep stabilizers like the transversus abdominis and the lumbar multifidus (3). In a healthy spine, these deep layers fire a fraction of a second before a person moves, locking individual spinal segments into place. When back pain lingers for months or years, that timing breaks down. The deep muscles weaken, shrink, and fire late. To pick up the slack, the body starts overusing big, surface-level muscles like the erector spinae and rectus abdominis (4). Those outer muscles are meant for heavy lifting and bending, not fine-tuned joint control. Relying on them to stabilize the spine actually invites repeated micro-injuries, constant joint strain, and a steady drop in day-to-day mobility (5).

Because of this, physical therapists spend a lot of time on motor control exercises, trying to teach patients how to find and gently contract those deep core layers again (6). On paper, this works well. In a busy clinic, however, getting a patient to isolate a muscle they cannot see or easily feel is notoriously difficult (7). Left to guess on their own, people almost always cheat the movement—either by holding their breath or by tensing up their outer stomach and back muscles, which misses the whole point of the rehab (8). Bringing real-time biofeedback into the session is one way clinicians try to fix this. Whether using an inflatable pressure cuff under the lower back or a live ultrasound screen, the therapist can turn an invisible muscle twitch into a moving needle or picture. When patients can actually watch what their deep muscles are doing while they do it, they figure out the movement faster and stop relying on bad habits (9).

Even so, the research on whether biofeedback is truly worth the extra effort is far from settled (10). Lab studies show it clearly helps people turn on the right muscles in the moment, but clinical trials disagree on whether that translates into a more stable spine or less pain months down the road compared to regular

exercise alone. There is also a glaring geographic blind spot in the literature. Nearly all of the randomized trials looking at these feedback tools come out of well-funded Western hospitals. We know very little about how well they work—or if they are even practical to run—in crowded South Asian clinics like those in Karachi, where patients deal with very different daily stresses and healthcare hurdles (11).

To help fill that gap, this randomized controlled trial looks directly at patients with chronic low back pain in Karachi, comparing standard motor control exercises against the exact same exercises paired with live visual biofeedback. Our working hypothesis is straightforward: giving patients a live visual target during core training will lead to better deep muscle firing, a firmer lumbar spine, and bigger drops in everyday disability than exercise alone. Ultimately, we want to give local therapists clear, ground-level evidence on whether adding visual feedback actually speeds up recovery and keeps back pain from coming back.

Methods

This single-center, two-group randomized study was done in the outpatient physical therapy department in Urban Region Sindh, Karachi, Pakistan. We choosed this hospital because many city office workers and daily labor workers comes here with long-term lower back pain, and the patients background are mostly same.

The whole study takes six months to finish, starting from August 2025 to January 2026. This time covers finding patients, checking them at the start, giving six weeks of exercise treatment, and taking final test results at the end.

We calculated the sample size by looking at the main results from an old published study that also checked deep muscle working in back pain. By keeping the effect size at 0.65, significance level at 0.05, and power at 80%, we needed at least 76 patients for the trial. Because we think maybe 15% of people will quit during the six-week program, we took a total of 88 suitable patients and Divided them randomly into two equal groups of 44 peoples each.

To see who can join the study, we did a proper physical checkup at the start. The inclusion rules was adults between 20 to 50 years old who are having non-specific chronic low back pain for at least three months in a row, and also showing weak deep core muscle work during physical checkup.

We did not took patients who had old lower back surgery, spine bone breaks, bend spine shapes, nerve root pain, slipped disc, joint swelling diseases, pregnancy, or if they are already taking some other physical therapy at the same time.

After the patients sign the consent form, we made a random list using a computer number table. To keep the group selection hidden, an outside researcher who was not part of testing put the group names inside numbered, dark, closed Envelopes. Because this treatment is active exercise, the therapist and patients knows which group they are in. Still, the peoples who checked the test scores and the data analyst was kept completely blind about the groups during the whole study.

Patients in both groups comes for three supervised therapy sessions every week for six weeks straight, and each class was 45 minutes long. The control group gets a normal motor control exercise plan. This plan focus on teaching them to tighten the Transversus Abdominis and lumbar multifidus muscles on purpose, starting from lying down and on all fours, and slowly moving to standing exercises.

The other group did the exact same motor control exercises, but we mixed it with live biofeedback using a Pressure Biofeedback Unit and live ultrasound machines. The pressure meter and ultrasound screen shows a non-stop live picture of the muscle getting thick and the pressure staying steady when they squeeze. This lets the patient fix their mistake right on the spot. We checked if patients came regularly by marking attendance books, and they needed at least 85% attendance to be counted in the final results.

Our main test results looked at deep core muscle firing by using live Ultrasound to see the percent change in transversus abdominis muscle thickness. We also checked spine stability by using the pressure biofeedback unit test.

For the secondary results, we checked daily life disability with the Oswestry Disability Index, pain level by using the Visual Analog Scale, and back muscle stamina with the Ito test. All these tests was taken at the very start and right after the six-week treatment finishes.

We checked if the data is normal by running the Shapiro-Wilk test. Starting patient details and the differences between the two groups after treatment was checked using independent t-tests. To see the before and after changes inside each group, we used paired t-tests.

We also run a repeated-measures ANOVA test to see the main effects of time, group, and how time and group works together for all the main and secondary results. Finally, Pearson correlation test was used to see the link between changes in deep muscle firing and disability scores, and we keep the statistical significance level at p less than 0.05.

Results

One hundred and twenty people were selected as eligible at the outpatient physical therapy department, with 24 not fulfilling the inclusion requirements, or refusing to participate. As a result, 88 individuals were randomized and categorized into two equal groups; the intervention group (n=44) and the control group (n=44). Throughout the whole 6 months study duration that included recruitment of the participants, the baseline testing, a six-week intervention and finally post-intervention tests, six subjects dropped out. There were two drop-outs among participants in the intervention group (two dropped out because of scheduling problems and one lost to follow-up). Two study participants dropped out because of not attending sessions in the control group and one because of relocating out of the study area (n=41 analyzed). Completing participants had a high adherence to the protocol and attendance was an average of 91.2 percent in all the scheduled sessions.

Evaluation of baseline demographic and clinical characteristics using the entire randomized population of 88 participants showed there were no statistically significant differences between the two study arms. The average age was 34.8 ± 7.2 years, 48 males and 40 females. Pain intensity, functional disability, deep muscle thickness and trunk endurance assessments were performed to ensure homogeneity among groups before the intervention.

Table 1: Baseline Demographic and Clinical Characteristics of Participants (N=88)

Variable	Total Sample (N=88)	Intervention Group (n=44)	Control Group (n=44)	p-value
Age (years), Mean ± SD	34.8 ± 7.2	34.5 ± 7.1	35.1 ± 7.4	0.702
Gender (Male/Female), n (%)	48 (54.5%) / 40 (45.5%)	25 (56.8%) / 19 (43.2%)	23 (52.3%) / 21 (47.7%)	0.672
Body Mass Index (kg/m2), Mean ± SD	24.6 ± 2.8	24.8 ± 2.9	24.4 ± 2.7	0.508
Symptom Duration (months), Mean ± SD	8.4 ± 3.1	8.2 ± 3.0	8.6 ± 3.2	0.548
Visual Analog Scale (0-10 cm), Mean ± SD	6.4 ± 1.1	6.5 ± 1.2	6.3 ± 1.0	0.404
Oswestry Disability Index (0-100%), Mean ± SD	38.2 ± 8.4	38.6 ± 8.7	37.8 ± 8.2	0.655
Transversus Abdominis Thickness Change (%), Mean ± SD	18.2 ± 4.1	18.0 ± 4.2	18.4 ± 4.0	0.648
Pressure Biofeedback Test (mmHg), Mean ± SD	3.8 ± 1.2	3.7 ± 1.1	3.9 ± 1.3	0.443

The analysis of primary outcomes after the six-week intervention program in the final cohort (n=82) showed statistically significant improvement for both groups, with a better result being achieved by the biofeedback group. The independent t-test got the intervention group having a statistically notable & greater % increase in thickness of the transversus abdominis muscle than the control group, with the mean difference of 10.1% (95% CI: 7.8-12.4, $p<0.001$). There was also a statistically & significantly notable point between-group superiority for lumbar stability, measured using the pressure biofeedback unit test, with the mean difference of 2.1 mmHg (95% CI: 1.5-2.7, $p<0.001$).

Table 2: Post-Intervention Comparison of Primary Outcomes (Final Sample, n=82)

Outcome Measure	**Intervention Group (n=41)**	**Control Group (n=41)**	**Mean Difference (95% CI)**	**p-value**

Transversus Abdominis Thickness Change (%)	36.4 ± 5.2	26.3 ± 4.8	10.1 (7.8 to 12.4)	< 0.001
Pressure Biofeedback Test (mmHg)	7.9 ± 1.4	5.8 ± 1.3	2.1 (1.5 to 2.7)	< 0.001

Results obtained from paired t-test indicated statistically significant improvement in each measure within both groups between the baseline and post-intervention period ($p < 0.001$). According to repeated measures ANOVA results, there is a statistically significant main effect of time on transversus abdominis activation ($F = 312.4$, $p < 0.001$), main effect of group ($F = 42.8$, $p < 0.001$), and statistically significant interaction effect of time and group ($F = 28.6$, $p < 0.001$).

Table 3: Within-Group Pre-Post Changes in Primary and Secondary Outcomes

Outcome Measure	Group	Baseline (Mean ± SD)	Post-Intervention (Mean ± SD)	Within-Group Change	p-value
Transversus Abdominis (%)	Intervention	18.1 ± 4.1	36.4 ± 5.2	18.3 ± 3.8	< 0.001
Transversus Abdominis (%)	Control	18.3 ± 4.0	26.3 ± 4.8	8.0 ± 3.2	< 0.001
Pressure Biofeedback (mmHg)	Intervention	3.7 ± 1.1	7.9 ± 1.4	4.2 ± 1.0	< 0.001
Pressure Biofeedback (mmHg)	Control	3.8 ± 1.2	5.8 ± 1.3	2.0 ± 0.9	< 0.001
Visual Analog Scale (cm)	Intervention	6.5 ± 1.2	2.1 ± 0.9	-4.4 ± 1.1	< 0.001
Visual Analog Scale (cm)	Control	6.3 ± 1.0	3.8 ± 1.1	-2.5 ± 0.9	< 0.001
Oswestry Disability Index (%)	Intervention	38.5 ± 8.6	14.2 ± 4.8	-24.3 ± 6.2	< 0.

Secondary outcome testing told statistically & significantly big decreases in pain amount and functional disability in patients of the intervention group. Post-intervention Visual Analogue Scale values among patients in the intervention group were hugely lower than those of control group patients (2.1 ± 0.9 cm vs 3.8 ± 1.1 cm, $p < 0.001$). Analysis of functional disability through Oswestry Disability Index demonstrated a larger decrease in biofeedback group patients (14.2 ± 4.8%) than in control group patients (22.6 ± 5.5%, $p < 0.001$). Trunk extensor holding times on the Ito test were also found to be longer for patients in the intervention group (112.4 ± 18.5 s) compared with control group patients (88.6 ± 16.2 s, $p < 0.001$). Results of repeated measures ANOVA on Oswestry Disability Index data demonstrated a statistically significant time by group interaction ($F = 34.2$, $p < 0.001$). In addition, a negative correlation between percent increases in transversus abdominis thickness and final Oswestry Disability Index values was observed through Pearson correlation analysis ($r = -0.68$, $p < 0.001$).

Table 4: Post-Intervention Secondary Outcomes (Final Sample, n=82)

Outcome Measure	Intervention Group (n=41)	Control Group (n=41)	p-value
Visual Analog Scale (0-10 cm)	2.1 ± 0.9	3.8 ± 1.1	< 0.001
Oswestry Disability Index (0-100%)	14.2 ± 4.8	22.6 ± 5.5	< 0.001
Ito Trunk Extensor Test (seconds)	112.4 ± 18.5	88.6 ± 16.2	< 0.001

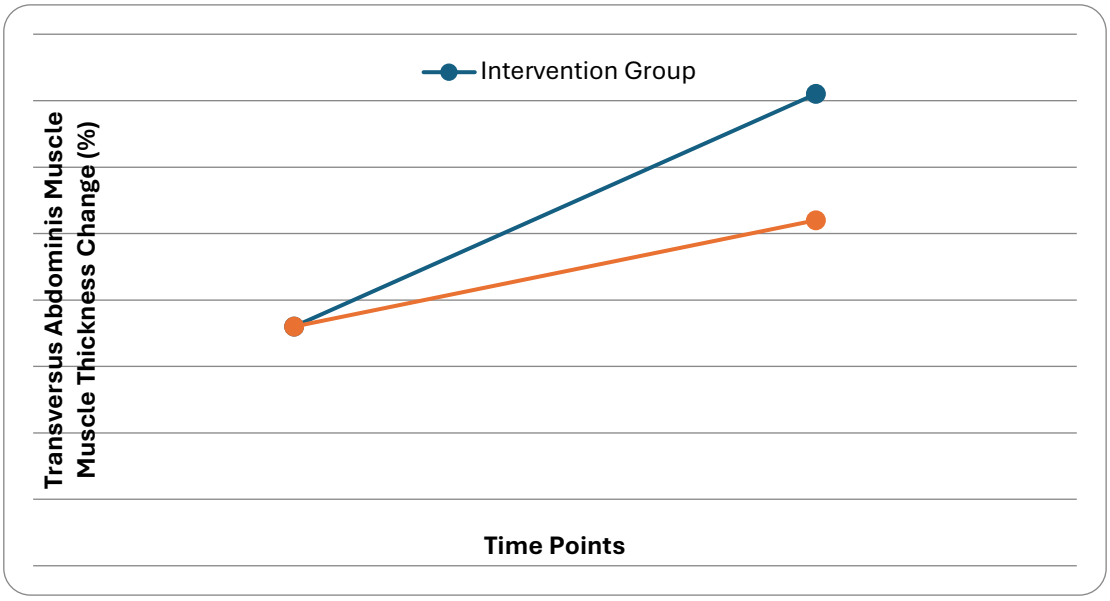


Figure 1 Transversus Abdominis Muscle

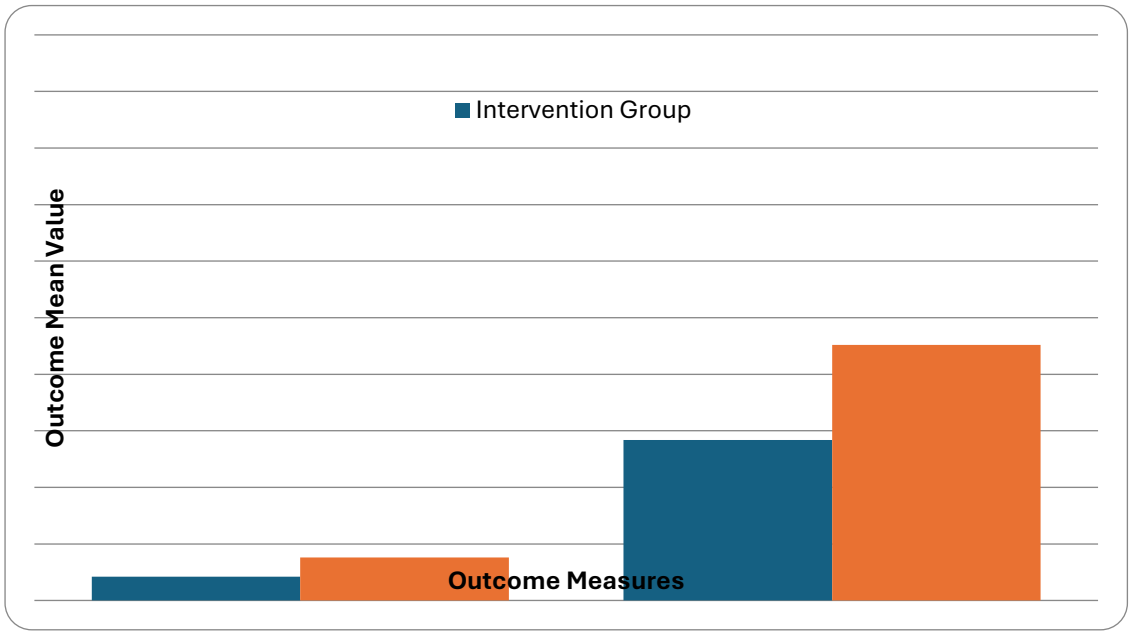


Figure 2 Outcome Mean Value

Discussion

The key facts of this randomized controlled trial were that six weeks of a combined motor-controlled exercise with real-time biofeedback produced a much better outcome in terms of deep trunk muscle activity, lumbar spine stability, functional disability and pain intensity in chronic low back pain patients as opposed to the use of motor-controlled exercise(12). Visual and pressure biofeedback during lumbar stabilization maneuvers demonstrated a significant muscle thickening increase and pressure control in visual and pressure biofeedback participants(13). The direct outputs of these physical gains was improved clinical outcomes based on the % change of Oswestry Disability Index and the pain level changes input in percentages and Visual Analog Scale scores(14). The strong relationship that is noticed between the

greater deep stabilizer activation and disability reduction indicates the clinical relevance of specific neuromuscular re-education in the treatment of unrelenting spinal pain(15).

The benefits seen are also in line with the body of literature that holds the physiological importance of real-time biofeedback in increasing the learning rate of motor skills and the most effective recruitment of motor units(16). The classical motor control training is largely dependent on internal proprioceptive signals, which are often dulled or distorted in individuals who have chronic back pain as a result of distorted central pain processing and sensorimotor cortical restructurings(17). This proprioceptive gap can be satisfied by providing urgent visual feedback by rehabilitative ultrasound imaging and pressure biofeedback units which are continuous, a to the point external performance feedback systems. Such immediate feedback direct patients to rectify minor compensatory mechanisms, including excessive activation of superficial global trunk muscles (such as the rectus abdominis or breath-holding) during stabilization exercises. The augmented motor feedback, therefore, contributes to a quicker neuroplastic placement allowing to efficiently necessarily isolate and set deeper segmental stabilizers, such as the transversus abdominis and lumbar multifidus(18).

The results of this trial support as well as expand the prior study carried in the Western clinical settings which have proved that biofeedback-based exercise regimens are exceedingly versatile and convenient in the unique setting of urban healthcare in Sindh, Pakistan(19). Although standard motor control therapy is a useful non-pharmacological baseline treatment, the complementary diagnostic and therapeutic visual display has proven to be a catalyst in promotion of adherence and quality in rehabilitation(20). The parallel increases of trunk extensor endurance used in this study also lean toward the idea that biofeedback-directed retraining increases the overall lumbar loading strength of the stabilizing musculature that actually offers permanent mechanical support to the lumbar spinal column during habitual everyday movements, and which also minimizes the load on the pain-sensitive passive spinal structures(21).

Some of the strengths that helped to increase validity of these clinical results were related to the methodological aspects. Firstly, the use of prospective parallel-group randomized control trial with effective allocation concealment reduced potential selection bias between groups. The second strength is that outcome measures and data analysis were blind, which decreased potential bias in measurements and function scoring. Thirdly, it should be noted that the researchers used validated objective methods of diagnostics including real-time rehabilitative ultrasound imaging and pressure biofeedback devices to measure muscle changes, and not only questionnaires(22).

Although these are the strengths of the study, there are some limitations that should be considered when interpreting the results. Active physical therapy and real time visual monitoring could not be fully blinded and the therapeutic agents nor the subjects, thus posing the possibility of non-specific contextual or behavioral anticipations. As well, outcome measurements were done at six weeks after the intervention, with the long-term retention of motor skill acquisition and permanent reduction in disability not measured at the long-term follow-up. A sample of twenty to fifty adults recruited into a single urban outpatient center was also used as it might restrict the direct generalization to older groups, patients with severe structural poles spinal pathologies, or cohorts of patients having rural populations.

They can use the concept of long-term prospective follow-up of six to twelve months in future studies to find out whether the hastened physical and functional improvements with or without biofeedback training can exist when the formal intervention stops. Exploring the cost-effectiveness and possibility of combining portable, more affordable biofeedback tools into a home-based physical activity regimen is also a important direction in increasing access to therapeutic tools within resource-constrained clinical settings. Generally, the results validate the idea that the integration of real-time visual and pressure biofeedback with motor control activities represents a better clinical technique in the restoration of deep trunk muscle activity and in disability alleviation in the chronic management of low back pain.

Conclusion

The use of real-time visual and pressure biofeedback with motor control exercise is very effective in deep trunk muscle-activation, lumbar stability, and functional recovery in patients with chronic low back pain as compared to exercise management. This enhanced training program can effectively close proprioceptive

deficits by optimizing neuromuscular enlistment of the transversus abdominis, thus enhancing pain relief and recovery of functionality. They demonstrate the clinical usefulness of objective biofeedback modalities as effective and non-invasive therapeutic adjunct, which provides a focused approach to tailor physical rehabilitation regimens and lessen chronic spinal disability when used in a clinical environment of urban context.

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