ORIGINAL ARTICLE

Motor Control Exercises With Real-time Ultrasound Feedback for Managing Pain and Disability Among Patients With Chronic Non-specific Low Back Pain

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ABSTRACT

Introduction: Non-specific Low Back Pain (NSLBP) is the fifth leading cause of absenteeism from workplace and its considered quite challenging to treat in physical-therapy because of the nature of recurrence. Among the wide range of exercises, identifying the most suitable patient-centric exercise is crucial in relieving symptoms. This study aims to assess the changes following administering motor control exercises (MCE) providing appropriate biofeedback, on pain and functional activity among patients with chronic NSLBP. **Materials and methods:** This quasi-experimental study with consecutive sampling had a control and experimental group with forty-eight participants in each group. The control group received lumbar stabilization exercises (LSE) and experimental group received MCE with real-time ultrasound (RTUS) biofeedback for a period of 8 weeks. The subjects were measured for pain and functional activity using Numeric Pain Rating Scale (NPRS) and Oswestry Disability Index (ODI). **Results:** Results of within group analysis of NPRS and ODI scores revealed that there was a significant difference in both groups which means both interventions were effective. However, between-group analysis revealed that from baseline homogeneity, there was a significant difference between two groups at the end of intervention with experimental group subjects displaying less pain and disability compared to the control group. **Conclusion:** This study concluded that MCE administered with RTUS biofeedback was significantly more effective than LSE in reducing pain and functional disability in patients with chronic NSLBP. Enhanced motor control precision through biofeedback may help physiotherapists to tailor interventions more effectively, making it a valuable addition to physical-therapy protocols for chronic NSLBP. *Malaysian Journal of Medicine and Health Sciences* (2025) 21(3): 287-294. doi:10.47836/mjmhs.21.3.33

Keywords: Non-specific low back pain, Numeric pain rating scale, Oswestry disability index, Motor control exercises, RTUS biofeedback

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INTRODUCTION

Non-Specific Low Back Pain (NSLBP) is identified as a major health issue worldwide. As the cause of pathology remains unidentified, this condition poses a serious challenge to the treating physical therapist both in clinical decision-making and treatment delivery. An experienced physical therapist should analyze the pain algorithm with in-depth anatomical knowledge and wise clinical decision-making to bring about a faster prognosis.

NSLBP is defined as low back pain not attributable to a recognizable, known specific pathology such as osteoporosis, infection, fracture, or inflammation (1). NSLBP can be acute, sub-acute or chronic based on duration of the ailment and it accounts for 65% of visits to a physical therapist (2). The lifetime prevalence of NSLBP is as high as 84% with chronic LBP being the commonest (3). The economic burden and the global disability caused by this condition cannot be underestimated (4). NSLBP is reported as a self-limiting condition, in which the majority of cases recover in three to four months with or without treatment and only around 10% are challenging cases that do not respond to treatment much and need intense physical therapy and are challenging to the professionals (5).

Management of NSLBP mainly depends on individual variability in pain behavior, high probability of recurrence, lack of treatment generalizability, and so on

(6). NICE guidelines recommends non-pharmacological management and physical therapy treatment as first-line approach for NSLBP rather than analgesics and imaging (7). It emphasizes the importance on staying active and doing exercises as a part and parcel of any treatment protocol to prevent further damage to the underlying tissues and helps in faster recovery (8). Individual muscle exercises have always been taught in many musculoskeletal conditions by physiotherapists. There are controversial claims for its advantages and disadvantages. As a breakthrough in physiotherapy management of NSLBP, a study revealed that considering NSLBP as a single condition (homogenous event) will not lead to identifying the appropriate and effective intervention and hence there is a need for subgrouping them to aid clinical decision-making (9). Hence identifying an appropriate intervention based on reliable tools categorising the sub-group of ailment is mandatory. In this study, chronic NSLBP was considered as the main sub-group, as there is poor evidence for exercises in acute NSLBP management already (10,11). Having opted for exercise as an intervention, there is no clear determination as of now to state which type of exercises are effective in the management of Chronic NSLBP. Some suggestions range from a home exercise program to supervised exercises, then to progress with the structured exercise regimen. However, there is no clear consensus to state if these interventions differed in their effect (12, 13). Chronic NSLBP can be categorized into movement impairment (MI) and movement control impaired (MCI) subjects.

It is well accepted that NSLBP is due to the lack of stability in spinal musculature (14, 15, 16) and patients have impairments in the control of deep trunk muscles especially the transversus abdominis, which is responsible for maintaining the coordination and stability of the spine (17). Based on the above principle Motor Control Exercises (MCE) were developed with the aim of restoring the coordination, control and capacity of the trunk muscles (18). MCE involves the training of isolated contraction of deep trunk muscles with integration of these deep muscles contraction into more complex static dynamic and functional tasks (19, 20). MCE intervention involves the coordination and optimal control of global trunk muscles as well (21, 22).

Motor control theories emphasize learning for normal movement patterns to occur. However, learned abnormal movements become an issue in terms of chronic NSLBP patients, and consecutively unlearning becomes tougher and poses a big challenge for the physiotherapist. Re-learning or re-education of the normal motor strategy is essential in the management of chronic NSLBP. The anticipatory recruitment of trunk muscles particularly the Transversus Abdominis (TrA) and the multifidus is found to be the basis for any trunk or limb movement. These two muscles contract before the limb muscles move and thereby stabilize the motion segments (23, 24). This anticipatory contraction is lost in NSPLBP patients and as a result, the entire movement gets distorted. When it comes to lumbar stabilization exercises or core stabilization exercises using the motor control retraining concept, there have been so many conflicting results in the past that promote more research with specific objectives and specified populations (25, 26). This might be mainly due to a lack of proper execution of the exercise as it is very difficult to contract these deeply seated muscles. Voluntary contraction of these muscles needs more precision and practice and it takes a lot of understanding from the patient who is already in pain. If there was a biofeedback mechanism to exactly provide the patient with guidance, it might be easier for the patients to enhance or correct their performance.

The novelty of applying MCE using non-invasive Real-time ultrasound imaging (RTUS) feedback for NSLBP patients highlights on the key aspect of providing real time feedback to both the patients and the physiotherapists. Activation of TrA and multifidus has always been challenging which is easily met with RTUS. Apart from this, the precise targeting of deep muscle contraction, improvement in motor learning, objective monitoring and progress tracking are the advantages of this RTUS. The visual biofeedback also helps in engagement of patients in performing the exercises and provides continued motivation to the doer.

This research aims to assess the effectiveness of Motor Control Exercises (MCE) combined with biofeedback in reducing pain and improving functional activity in patients with chronic non-specific low back pain (NSLBP). The study will compare these outcomes with the traditional lumbar stabilization program typically administered to such patients.
The objectives of this research are as follows

- To evaluate the effects of Motor Control Exercises on pain reduction in patients with Chronic Non-Specific Low Back Pain.
- To evaluate the effects of Motor Control Exercises on improving functional activity in patients with Chronic Non-Specific Low Back Pain.

MATERIALS AND METHODS

The study is a Quasi-experimental study with a control group and experimental group with an allocation ratio of 1:1 with 48 subjects in each group. The subjects were selected if they were clinically diagnosed by the Physician as Chronic Non-Specific Low Back Pain (CNSLBP) from the outpatient department of two medical clinics and through consecutive sampling method, 96 subjects were finalised for the study and were allocated randomly into either of the groups – Control group and Experimental group by a random table method. The primary researcher was not aware of the process of randomization and came to know the

group only on the day of first session of intervention. The study was approved by The University Research Review Committee of MAHSA University (Ethical approval number MAHSA/RRC-FHSS/10-17(25)). All the subjects were briefed about the research process and an informed consent was obtained.

Subjects with a history of CNSLBP affecting their functional activity and between the age group of 35 and 55 years of both genders were included in the study. Subjects who were clinically diagnosed by a Physician as CNSLBP for a duration of 12 weeks at least were included in the study.

Subjects with a history of radiating pain to either of the limbs, tingling sensation, paraesthesia in any of the lower limbs, recent spinal fracture, spinal stenosis, spondylolisthesis, spondylitis, spondylolysis, spinal deformities were excluded from the study. Subjects with unstable medical condition like severe hypertension, uncontrolled diabetes, cardiovascular disorders, neurological deficit and mental instability were excluded from the study.

After the subjects were randomly allocated into the respective groups, a pre-test measurement for pain and functional activity were done using Numeric Pain Rating Scale (NPRS) and Oswestry Disability Index (ODI). NPRS is a unidimensional measure of pain intensity in adults that examines the responsiveness pain characteristics with a 11 point numeric scale with 0 at one end and 10 at other end, where zero represents no pain and ten represents worst possible pain (27). ODI is a patient-completed questionnaire which gives a subjective percentage score of level of function (disability) in activities of daily living in those rehabilitating from low back pain (28). Various parameters of pain are measured with each item consisting of 6 statements with a score of zero to five, where zero stands for least disability and five greatest disability. The total score is taken as percentage.

The experimental Group received MCE that was individualized and taught by a specially trained physical therapist according to a protocol on therapeutic exercise for lumbopelvic stabilization using RTUS feedback. The ultrasound equipment used was Full Digital Ultrasonic Diagnostic System (Version: V1. 3, PN NO.: WED-20-11050410E) manufactured by Shenzhen Well.D Medical Electronics Co. Ltd. Software version: V1.6.1.2 with standard musculoskeletal settings and the Curvilinear Convex Array (C3-1/60R/3-5 MHz) probe having a maximal detect depth of penetration upto +/- 190 mm was used to provide real-time feedback to patient. Hypoallergic water-based ultrasound gel was used as a coupling medium for ultrasound. A frequency of 5 MHz was set to visualize the Transversus Abdominis (TrA) muscle while using the above-mentioned equipment.

Participants were positioned in supine lying with a pillow under the knees with ultrasound probe placed in transverse orientation on the anterolateral aspect of the abdominal wall (29) halfway between the iliac crest and inferior border of rib cage as shown in Figure 1(a) and the ultrasound probe moved until the best possible visualization of the lateral abdominal muscles as shown in Figure 1(b) and once visualization of TrA achieved participants were instructed to do Abdominal Drawing in Maneuver exercise and to watch the ultrasound screen with therapist's guidance to receive real-time feedback about the contraction of their TrA.

Figure 1: Ultrasound probe placement and visualization of abdominal muscles in Figures 1(a) and 1(b). (a) Placement of Ultrasound Probe in the lateral abdominal wall. (b) Real time ultrasound Imaging of the Abdominal Wall at rest visualizing Transversus Abdominis, External and Internal Oblique.

The execution of MCE program involved 2 stages in which the duration of Stage 1 was the first 4 weeks (weeks 1 – 4) which comprises the cognitive and associative phases of MCE whereas the Stage 2 is the next 4 weeks (weeks 5 – 8) which comprised the autonomous phase of MCE (21). Each participant progressed through the stages according to specific criteria that should have been met in each stage.

In Stage-1 training, the coordinated activity of the trunk muscles, including independent activation of the transversus abdominis, was initiated, and reducing over activity of specific superficial muscles was done in an individualized manner with RTUS feedback. These exercises were supplemented with exercises for the pelvic floor muscles, breathing control, and control of spinal posture and movement. The specific muscles that were trained depended on the initial assessment. RTUS biofeedback that was directly fed into the patient's attention which was used to enhance the learning of the tasks of transversus abdominis training. The stage 1 training (Weeks 1 – 4) of TrA muscle was continued until the patients were able to maintain the isolated contractions of TrA muscle for ten repetitions of ten seconds each while maintaining normal respiration. When this level of competence was achieved, patients were considered ready to progress to the next stage. In Stage 2 (weeks 5 – 8), the patients were positioned in fowlers position and the activation of TrA muscle

from static to dynamic position through the movement of hips and knees making the static into dynamic tasks in functional positions. The exercise program involved increasing the complexity by changing the fowlers position from low to semi fowlers position and the exercises progressed with functional tasks (like holding a ball, changing a ball from hand to hand) while attempting to maintain the TrA contraction and these exercises targeting coordination of trunk and limb movement, maintenance of optimal trunk stability, and improvement of posture and movement patterns.

Participants received 12 sessions of treatments for 30 minutes over eight weeks (Two sessions per week in the first Four weeks & and One session in the second Four weeks). Control group participants received Lumbar stabilization exercises for the same specific period as mentioned above for motor control exercises. The subjects were trained without the Real-time ultrasound biofeedback, using manual guidance and auditory feedback alone by the therapist. A post-test was taken for both outcome measures at the end of eight weeks.

Statistical analysis

The SPSS 25 version of software was used for computing the statistics of this study. The significance level for the study was fixed at 0.05 with a confidence interval of 95%. Chi square analysis was done to analyze the baseline homogeneity between the demographic data of the subjects.The homogeneity of data and normal distribution were analyzed through the Shapiro-wilk test and Kolmogorov-Smirnov test. The within-group analysis of parametric score was done through Paired t-test and between group was done and between group analysis was done through an Independent t-test.

RESULTS

There were 96 subjects who accounted for the study results. The demographic datawere analyzed for the baseline homogeneity. The data were distributed normally as per Kolmogorov-Smirnova and Shapiro-Wilk test and represented in Table I.

Table I: Statistical test of normality

Outcome Measure	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	Degree of freedom	Significance	Statistic	Degree of freedom	Significance
Numerical Pain Rating Scale	1.98	96	0.197	2.942	96	0.105
Oswestry Disability Index	2.14	96	0.207	3.457	96	0.166

The demographic data of the subjects - distribution of age, sex, duration of ailment, presence of radiating symptoms, and side of predominance of pain was assessed and presented in Table II for group differences and the results showed that groups were homogenous in all the criteria except the duration of ailment where the subjects in the experimental group were more chronic than the control. Hence, any changes that occurred in the dependent variable should be mostly because of the independent variable. Figure 2(a) shows the gender distribution of samples within control and experimental groups and Figure 2(b) shows the age distribution of samples within control and experimental groups for this study.

Table II: Analysis of the demographic data

Criteria	Control Group	Experimental Group	Significance
Age			
35-40	19	23	**Chi-square** =
41-45	16	12	2.134
46-50	12	10	P = 0.545
51-55	01	03	
Sex			**Chi-square** =
Male	30	27	0.3887
Female	18	21	P = 0.5330
Duration of ailment	14.5	18.72	**t-test** t=7.276 P=0.024
Radiating symptoms			
Yes	11	14	**Chi-square =**
No	37	34	0.486 P = 0.485
Side predominance			
Right	6	7	**Chi-square** =
Left	5	7	0.537
Central/bilateral	37	34	P = 0.764

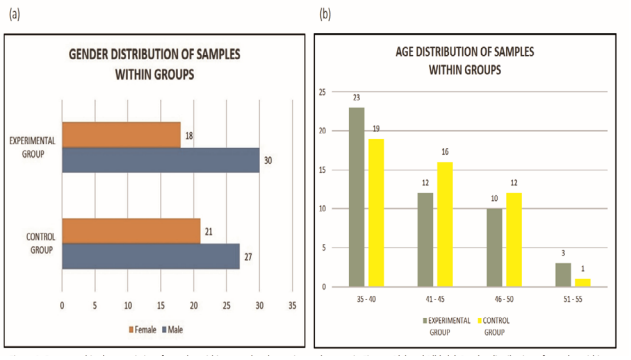

Figure 2: Demographic characteristics of samples within control and experimental groups in Figures 2(a) and 2(b). (a) Gender distribution of samples within groups. (b) Age distribution of samples within groups.

The primary outcome measures were analyzed for both within-group differences and between-group differences using parametric tests respectively. The within-group analysis of the ODI and NPRS scores revealed that there was a significant difference (at P<0.05) between the temporal variables in both groups which means both interventions were effective in reducing pain and functional activity (Table III). Figure 3(a) displays Pre and Post test mean for Numerical Pain Rating Scale and Oswestry Disability Index within groups and

Figure 3(b) Mean difference for Numerical Pain Rating Scale and Oswestry Disability Index between control and experimental groups. However, the between-group analysis using independent t-test revealed that from a baseline homogeneity, there was a remarkable difference between the control and experimental groups as shown in Table IV. At the end of the intervention with experimental group subjects displaying less pain and disability compared to the control group with a significant difference (at P<0.05) which showed that experimental group is more effective in reducing pain and improving functional activity when compared with control group. Figures 4A and 4B display the difference of mean values of NPRS and ODI between control and experimental groups.

Table III: Within-group analysis of the outcome measures

Outcome Measure / Group	Test	N	Mean	Standard Deviation	t-value	P value
NPRS-Control Group	PRE TEST	48	7.79	0.922	-23.27*	0.001
	POST TEST	48	3.44	1.109		
NPRS-Experimental Group	PRE TEST	48	7.75	0.786	-50.470*	0.001
	POST TEST	48	0.71	0.651		
ODI-Control Group	PRE TEST	48	67.49	9.162	-20.549	0.013
	POST TEST	48	34.02	10.606		
ODI-Experimental Group	PRE TEST	48	69.40	10.138	-28.422*	0.001
	POST TEST	48	11.71	9.594		
	Total			96		

Notes: *NPRS – Numerical Pain Rating Scale; *ODI – Oswestry Disability Index
*Statistically significant difference at P<0.05

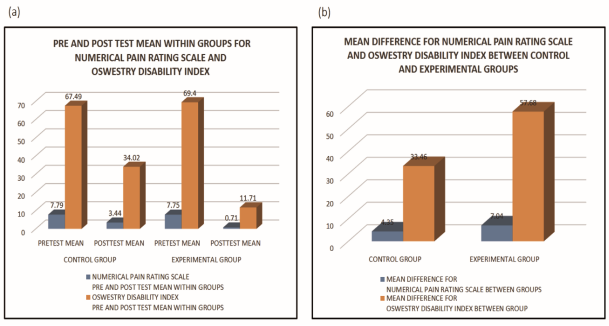

Figure 3: Mean for outcome measures within groups and Mean difference between groups in Figures 3(a) and 3(b). (a) Pre and Post test mean for Numerical Pain Rating Scale and Oswestry Disability Index within groups. (b) Mean difference for Numerical Pain Rating Scale and Oswestry Disability Index between control and experimental groups.

Table IV: Between-group analysis of the outcome measures

Outcome Measure / Test	Groups	N	Mean	Standard Deviation	t-test	P-value
NPRS-PRE TEST	Control Group	48	7.79	0.92	0.238	0.812
	Experimental Group	48	7.75	0.79		
NPRS-POST TEST	Control Group	48	3.44	1.11	14.70*	0.001
	Experimental Group	48	0.71	0.65		
ODI-PRE TEST	Control Group	48	67.49	9.162	1.124	0.644
	Experimental Group	48	69.40	10.138		
ODI-POST TEST	Control Group	48	34.02	10.606	28.15*	0.001
	Experimental Group	48	11.71	9.594		
	Total			96		

Notes: *NPRS – Numerical Pain Rating Scale; *ODI – Oswestry Disability Index
*Statistically significant difference at P<0.05

DISCUSSION

Chronic NSLBP has remained a major health issue with a high prevalence (30). While continuous research had always been conducted to overcome this problem, there was still a significant gap in engaging the core muscles and helping patients understand the importance of activating the TrA and multifidus. It was mainly because the exercise was not always willingly performed by the patients or even if done was not done targeting the exact group of muscles needed (31). Hence this study was conducted with among 96 subjects between the age group of 35 and 55 years of both genders who had complaints of low back pain for 12 weeks duration. The study compared the lumbar stabilization exercises against the motor control exercises with RTUS feedback for a period of eight weeks. The results of the study showed that both the groups performed well in both outcome measures. However, the subjects in the experimental group showed a better improvement than the control group participants in the standing, weight lifting, and walking component of the ODI. This is in line with the meta-analysis of the previous study that judged that MCT (motor Control Training) was effective in reducing the pain and disability associated with chronic back pain among community dwelling adults (32). This is due to the fact that the MCE can reduce the

over activity (33) of certain group of muscles and also at the same time reduce the muscle fatigue (34) thereby maintaining the properties of the contractile structure (35). The integration of biofeedback with the performance of exercise has helped the participants achieve the activation of the target muscle more precisely in the experimental group. This techno-assisted exercise has proven results in adaptive functions of core muscles with a proportional increase in type I fibers (36). The ability to observe and correct the muscle activation patterns in real time ensures that exercises are optimized for each patient, addressing specific imbalances or dysfunctions contributing to CNSLBP (37). The study displays high coherence in the conductance of the research because of the interactive element that increased the motivation of the participants and adherence to the rehabilitation program. This approach allows clinicians to dynamically assess a patient's performance and adjust the rehabilitation plan accordingly (38).

The novelty of the current is the incorporation of real-time ultrasound feedback into motor control exercises which is a distinct feature. The precision achieved through real-time ultrasound feedback allows for a more tailored and individualized rehabilitation approach. This adaptability ensures that the exercises evolve with the patient's progress and changing needs, making the intervention more responsive and effective over time. The study may contribute to a deeper understanding of muscle activation patterns in individuals with CNSLBP by utilizing RTUS. Researchers and clinicians can gain insights into how specific muscles respond to various exercises and how these patterns correlate with pain reduction and functional improvements.

CONCLUSION

This study concludes that motor control training when provided along with real-time ultrasound biofeedback is an effective intervention tool in managing pain a disability associated with chronic NSLBP. Future studies should concentrate on providing pain counselling along with MCT in countering other ailments associated with chronic NSLBP.

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