

EFFECTS OF WHOLE-BODY ELECTROMYOSTIMULATION TRAINING ON PAIN, FUNCTIONAL DISABILITY, AND ENDURANCE IN INDIVIDUALS WITH CHRONIC LOW BACK PAIN

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Abstract

Background: Chronic low back pain (CLBP) is a prevalent musculoskeletal disorder associated with persistent pain, functional limitations, impaired trunk muscle endurance, and reduced physical functioning. Whole-body electromyostimulation (WB-EMS) has emerged as a time-efficient adjunct to exercise-based rehabilitation; however, its effectiveness when combined with conventional physiotherapy remains insufficiently established.

Objective: To compare the effects of WB-EMS combined with conventional physiotherapy and conventional physiotherapy alone on pain intensity, functional disability, and trunk muscle endurance in individuals with CLBP.

Methods: A randomized controlled trial was conducted over a six-month study period among 48 individuals aged 20–40 years with CLBP. Participants were randomly allocated to either a WB-EMS group (n = 24), receiving WB-EMS combined with low-intensity exercises and conventional physiotherapy (CPT), or a CPT group (n = 24), receiving stretching, strengthening, and postural correction exercises. Both groups received treatment twice weekly for 12 weeks. Pain intensity, functional disability, and trunk muscle endurance were assessed using the Numeric Pain Rating Scale (NPRS), Oswestry Disability Index (ODI), and standardized trunk endurance tests, respectively. Data were analyzed using appropriate non-parametric statistical procedures.

Results: Both groups demonstrated significant improvements in pain intensity, functional disability, and trunk muscle endurance following the intervention ($p < 0.001$). Between-group analysis demonstrated significantly greater improvements in pain intensity ($p = 0.010$) and functional disability ($p < 0.001$) in the WB-EMS group compared with the CPT group. Significant between-group differences were also observed in flexor endurance ($p < 0.001$), extensor endurance ($p < 0.001$), and left-side bridge endurance ($p = 0.010$). However, no significant between-group difference was observed in right-side bridge endurance ($p = 0.557$).

Conclusion: Both rehabilitation approaches produced significant improvements in clinical outcomes among individuals with CLBP. However, the addition of WB-EMS to conventional physiotherapy resulted in superior improvements in pain, functional disability, and selected measures of trunk muscle endurance compared with conventional physiotherapy alone. WB-EMS may therefore represent a beneficial adjunct to conventional rehabilitation for improving clinical and functional outcomes in individuals with CLBP.

1. INTRODUCTION

Chronic low back pain (CLBP) is a prevalent musculoskeletal condition characterised by pain or discomfort between the lower costal margin and inferior gluteal folds persisting for more than 12 weeks. It is often recurrent and multifactorial, with mechanical, muscular, postural, lifestyle, and psychosocial factors contributing to its persistence [1,2]. As a major cause of disability worldwide, CLBP substantially affects physical functioning, productivity, and quality of life, particularly among working-age adults [3]. In Pakistan, its considerable prevalence further underscores the need for effective and accessible rehabilitation strategies [4,5].

The pathophysiology of CLBP involves altered neuromuscular control, impaired trunk muscle function, persistent nociceptive input, and, in some individuals, central sensitisation [6,7]. These impairments may result in pain, restricted movement, reduced trunk muscle endurance, and functional limitations in activities such as bending, lifting, walking, and prolonged sitting [8–10]. Although pharmacological treatments may provide symptomatic relief, physiotherapy and exercise-based rehabilitation remain central to conservative management, with evidence supporting improvements in pain, strength,

endurance, functional capacity, and psychological well-being [11–14]. Nevertheless, pain, fatigue, fear of movement, and poor adherence may limit participation in conventional exercise programmes.

Whole-body electromyostimulation (WB-EMS) is an emerging rehabilitation modality that delivers electrical impulses through surface electrodes to stimulate multiple muscle groups simultaneously [15]. By promoting muscular activation with relatively low mechanical loading and short training durations, WB-EMS may complement conventional physiotherapy, particularly in individuals with reduced exercise tolerance [16]. Potential benefits include enhanced muscular strength, neuromuscular activation, physical performance, and pain modulation [17].

Despite growing interest in WB-EMS, evidence regarding its adjunctive effectiveness in CLBP remains limited, particularly across pain intensity, functional disability, and trunk muscle endurance. Therefore, the present study compared WB-EMS combined with conventional physiotherapy with conventional physiotherapy alone in individuals with CLBP. It was hypothesised that the addition of WB-EMS would result in greater improvements

in pain, functional disability, and trunk muscle endurance.

2. Critical Analysis of Existing Literature

The existing literature suggests that whole-body electromyostimulation (WB-EMS) may be beneficial for managing chronic low back pain (CLBP), particularly in reducing pain and improving muscular performance; however, evidence remains insufficient to establish its superiority over conventional rehabilitation. Konrad et al. reported significant improvements in pain and disability following WB-EMS, with outcomes comparable to multimodal treatment, suggesting potential as a time-efficient rehabilitation strategy [16]. Similarly, Micke et al., in a multicentre randomised controlled trial of 240 patients, found comparable improvements in pain and trunk strength across WB-EMS, whole-body vibration, and conventional back-strengthening groups, although WB-EMS required substantially less training volume [20]. Baseline pain severity may influence treatment response, with greater reductions observed among participants with higher initial pain; however, this does not establish baseline severity as an independent predictor of treatment success [21]. Silvestri et al. also reported improvements in pain, disability, and flexibility, particularly when stretching was combined with WB-EMS, although the small sample and non-randomised design limit causal inference and generalisability [18]. Ayala's proposed controlled investigation further supports interest in combining WB-EMS with lumbar stabilisation, but provides a rationale rather than definitive evidence [22].

Indirect evidence from other populations is similarly promising but cannot be directly extrapolated to CLBP. Evangelista et al. demonstrated improvements in functional fitness and muscular characteristics following WB-EMS combined with exercise, whereas Zink-Rückel et al. observed improvements in trunk and leg strength and lean body mass without significant improvement in low back pain, indicating that increased muscular capacity may not necessarily

produce clinically meaningful pain reduction [19,23]. Research on alternative rehabilitation strategies has additionally highlighted the importance of accessibility, adherence, and evidence-based treatment selection in CLBP management [24–26].

Overall, the evidence is limited by substantial heterogeneity in participant characteristics, stimulation parameters, intervention duration, treatment frequency, accompanying exercises, comparator interventions, and outcome measures. Small samples, short intervention periods, non-randomised designs, and non-representative populations further restrict external validity. Moreover, existing research has focused predominantly on pain, disability, and muscular strength, while trunk muscle endurance has received comparatively limited attention despite its relevance to sustained functional activity.

A further gap concerns the limited evidence from Pakistan. Although Saeed et al. demonstrated the relevance of validated outcome measures for assessing low back pain within the Pakistani population, their study did not investigate WB-EMS as a physiotherapy intervention [4]. Consequently, the effectiveness and clinical applicability of WB-EMS within the Pakistani rehabilitation context remain uncertain. Differences in healthcare accessibility, occupational demands, physical activity, adherence, and rehabilitation practices may influence treatment outcomes.

Therefore, an important evidence gap remains regarding whether adding WB-EMS to conventional physiotherapy provides greater benefits than conventional physiotherapy alone, particularly for pain intensity, functional disability, and trunk muscle endurance. The present study addresses this gap by directly comparing WB-EMS combined with conventional physiotherapy with conventional physiotherapy alone over a structured 12-week intervention, providing locally relevant evidence on its clinical and functional effectiveness in individuals with CLBP.

3. Objectives and Hypothesis

The objective of this study was to compare the effects of a 12-week whole-body electromyostimulation (WB-EMS) training program combined with conventional physiotherapy (CPT) versus CPT alone on pain intensity, functional disability, and trunk muscle endurance in individuals with chronic low back pain. The null hypothesis (H_0) stated that there would be no significant between-group differences in pain intensity, functional disability, or muscle endurance following the intervention, whereas the alternative hypothesis (H_1) stated that the addition of WB-EMS to conventional physiotherapy would significantly reduce pain intensity and functional disability and improve trunk muscle endurance compared with conventional physiotherapy alone.

4. Problem Statement

Chronic low back pain (CLBP) is a prevalent musculoskeletal condition associated with persistent pain, functional disability, reduced physical capacity, and impaired quality of life. Although conventional physiotherapy and exercise-based rehabilitation are widely used, their effectiveness may be limited by prolonged treatment duration, poor adherence, and reduced exercise tolerance. Whole-body electromyostimulation (WB-EMS) is a time-efficient, relatively low-load modality that simultaneously activates multiple muscle groups and may improve pain, functional performance, and trunk muscle capacity.

However, evidence regarding the additional benefits of WB-EMS combined with conventional physiotherapy remains limited, particularly for pain intensity, functional disability, and trunk muscle endurance. Evidence from Pakistan is also scarce. Therefore, this study was conducted to determine whether adding WB-EMS to conventional physiotherapy provides greater clinical and functional benefits than conventional physiotherapy alone in individuals with CLBP.

5. MATERIALS AND METHODS

5.1 Study Design and Setting

A randomized controlled trial was conducted at EMS Fitness Studio by Aura, Sialkot, Pakistan, over a period of six months following approval of the study synopsis. The study investigated the effects of whole-body electromyostimulation (WB-EMS) combined with conventional physiotherapy compared with conventional physiotherapy alone in adults with chronic low back pain (CLBP).

5.2 Participants and Sample Size

A total of 48 participants, comprising males and females aged 20–40 years, were recruited and equally allocated to two groups ($n = 24$ per group). The required sample size was estimated using G*Power version 3.1.9.7, assuming an effect size of Cohen's $d = 0.90$, a significance level of $\alpha = 0.05$, and adequate statistical power to detect a significant between-group difference. The calculation was informed by a previous study involving 40 participants [18], while the final sample was increased to 48 participants to improve statistical power. Participants were initially recruited through purposive sampling and subsequently randomly allocated to either the WB-EMS or conventional physiotherapy (CPT) group.

5.3 Eligibility Criteria

Participants were included if they were aged 20–40 years, had experienced CLBP for more than 12 weeks, reported a baseline pain intensity of ≥ 5 on the Numeric Pain Rating Scale (NPRS), and were capable of performing moderate physical exercise. Participants were excluded if they had a history of spinal surgery or major spinal deformity, neurological disorders affecting motor function, cardiac conditions or contraindications to electrical muscle stimulation, or pregnancy.

5.4 Randomization and Intervention

Following informed consent and baseline assessment, participants were randomly allocated to either the Whole-Body Electromyostimulation (WB-EMS) group or the Conventional Physical Therapy (CPT) group. Both groups received the same standardized conventional physical therapy

exercise program under supervision for 12 weeks, with two sessions per week. The CPT program consisted of 45–60-minute s. In addition to the conventional physical therapy program, participants in the WB-EMS group received an additional 20-minute WB-EMS session involving low-intensity functional and stabilization exercises with electrical stimulation. The CPT group performed the same conventional physical therapy program without electrical stimulation. Detailed intervention protocols for both groups are presented in Tables 1 and table 2.

CPT = 45–60 min; WB-EMS group = same CPT + additional 20-min WB-EMS.

WB-EMS Group

Participants in the WB-EMS group performed the standardized conventional physiotherapy exercises while wearing a WB-EMS electrode suit. The detailed exercise protocol, including the targeted

muscle groups and specific exercises, is presented in Table 1. Before each session, the skin was inspected and the electrodes were appropriately positioned over the targeted muscle groups to ensure adequate contact. Electrical stimulation was applied during the prescribed exercises, with intensity individually adjusted according to participant tolerance and safety. Exercise and stimulation intensity were progressively modified according to individual improvement and tolerance. Participants were continuously monitored for discomfort, excessive muscle fatigue, dizziness, skin irritation, or other adverse effects. If any adverse symptoms occurred, stimulation intensity was reduced or the intervention was temporarily discontinued. All sessions were supervised by a qualified physiotherapist to ensure correct exercise performance, appropriate stimulation, and participant safety.

Table 1: WB-EMS Group Intervention Protocol

Component	Details
Duration	12 weeks
Frequency	2 sessions per week
Session Length	20 minutes per session
Target Muscles	Rectus abdominis, transversus abdominis, internal and external obliques, multifidus, erector spinae, quadratus lumborum, gluteus maximus, gluteus medius, hip stabilizers, and major lower-limb muscles
Exercises	Pelvic tilts, abdominal draw-ins, front planks, side bridges, bridging, squats/mini-squats, hip abduction, hip adduction, trunk extension, and other core stabilization and functional strengthening exercises
Modality	Whole-Body Electromyostimulation (WB-EMS) with low-frequency bipolar electrical stimulation combined with low-intensity functional and stabilization exercises

CPT Group

The CPT group received the same standardized exercise-based rehabilitation program without electrical stimulation for 12 weeks, with two supervised sessions per week, each lasting 45–60 minutes. The program incorporated aerobic warm-up, stretching of the hamstrings, hip flexors, gluteal and lumbar musculature, core stabilization exercises including pelvic tilts, abdominal draw-

ins, planks and side bridges, lumbar and lower-limb strengthening exercises, and postural and functional training. Progression was achieved through appropriate increases in repetitions, resistance, and task complexity according to participant tolerance and functional improvement. Detailed intervention components are presented in Table 2.

Table 2: Intervention Protocol for the Conventional Physical Therapy (CPT) Group

Component	Details
Duration	12 weeks
Frequency	2 sessions per week
Session Length	45–60 minutes per session
Target Muscles	Rectus abdominis, transversus abdominis, internal and external obliques, multifidus, erector spinae, quadratus lumborum, gluteus maximus, gluteus medius, hip stabilizers, and major lower-limb muscles
Exercises	Warm-up, stretching, pelvic tilts, abdominal draw-ins, planks, side bridges, bridging, squats, mini-lunges, hip abduction and adduction, lumbar extension, postural correction, functional training, and cool-down exercises
Modality	Conventional physical therapy comprising aerobic warm-up, stretching, strengthening, core stabilization, postural correction, functional training, and cool-down exercises

5.5 Outcome Measures

Outcome assessments were performed at baseline and immediately after completion of the 12-week intervention by assessors blinded to group allocation.

5.5.1 Pain Intensity

Pain intensity was assessed using the 11-point Numeric Pain Rating Scale (NPRS), ranging from 0 (no pain) to 10 (worst possible pain) [27]. Scores of 1–3, 4–6, and 7–10 represent mild, moderate, and severe pain, respectively. A reduction of approximately 2 points or 30% from baseline is generally considered clinically meaningful.

5.5.2 Functional Disability

Functional disability was assessed using the Oswestry Disability Index (ODI), a 10-item patient-reported measure specifically designed to assess disability associated with low back pain [28–30]. Each item is scored from 0 to 5, with the total score converted to a percentage ranging from 0% to 100%. Higher scores indicate greater disability. Scores of 0–20%, 21–40%, 41–60%, 61–80%, and 81–100% indicate minimal, moderate, severe, crippling, and bed-bound disability, respectively.

5.5.3 Trunk Muscle Endurance

Trunk muscle endurance was assessed using the McGill trunk endurance test battery, comprising the trunk flexor endurance test, trunk extensor

endurance (Sorensen) test, and right and left side-bridge tests. The flexor test assessed abdominal muscle endurance, the Sorensen test evaluated trunk extensor and lumbar muscle endurance, while the right and left side-bridge tests assessed lateral trunk endurance, particularly the oblique and quadratus lumborum musculature [31–33]. Each test was scored according to the maximum duration (in seconds) for which the participant could maintain the standardized position correctly, with longer holding times indicating greater trunk muscle endurance and shorter durations indicating reduced endurance. The McGill endurance tests demonstrate good-to-excellent reliability, with reported intraclass correlation coefficients (ICC) of approximately 0.80–0.89, and have established validity for evaluating trunk muscle endurance [31–33]. The primary outcome was the change in endurance time from baseline to post-intervention for each test. Although flexion-to-extension and side-bridge-to-extension ratios can be used to examine potential trunk muscle imbalance, the present study focused on absolute endurance times and their changes following the 12-week intervention.

5.6 Data Collection Procedure

Baseline measurements of pain intensity, functional disability, and trunk muscle endurance were obtained before initiation of the intervention. Participants subsequently completed

their assigned 12-week rehabilitation program. Immediately following completion of the intervention, all outcome measures were reassessed using the same standardized procedures employed at baseline. Assessments were performed by blinded assessors to minimize measurement bias. All collected data were recorded using coded data collection forms to ensure participant confidentiality and were subsequently entered into IBM SPSS Statistics version 26.0 for statistical analysis.

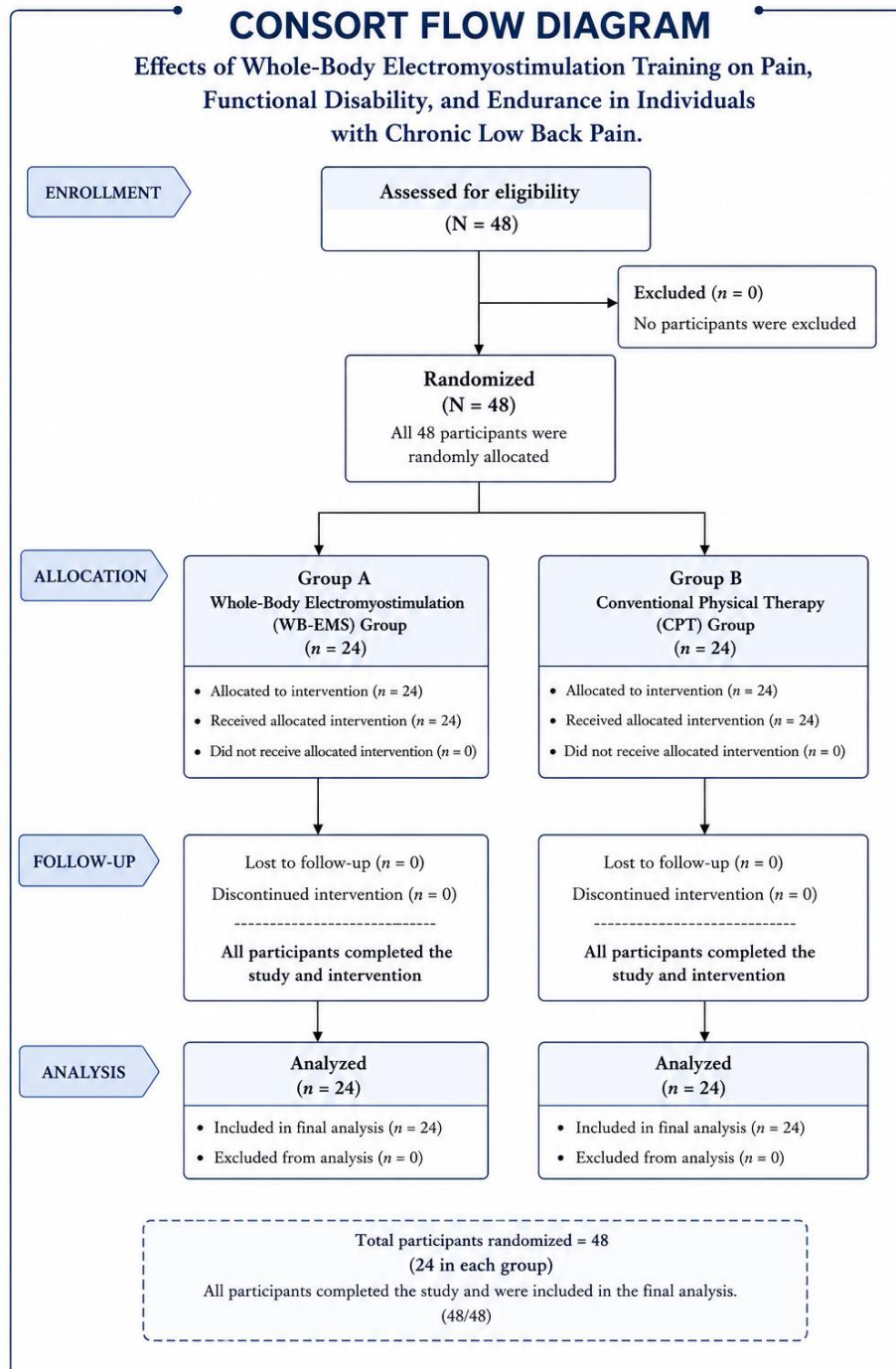
5.7 Statistical Analysis

The collected data were analyzed using IBM SPSS Statistics version 26.0. Descriptive statistics, including mean, standard deviation, frequency, and percentage, were used to summarize the study data. The Shapiro-Wilk test was applied to assess the normality of the data. For within-group comparisons, pre- and post-intervention scores were analyzed using the Wilcoxon signed-rank test. For between-group comparisons, post-intervention scores and change scores were compared between

the CPT and WB-EMS groups using the Mann-Whitney U test. A p-value ≤ 0.05 was considered statistically significant.

5.8 Ethical Considerations

Ethical approval was obtained from the relevant institutional review board before commencement of the study. Written informed consent was obtained from all participants after they had been informed about the study objectives, procedures, potential risks and benefits, confidentiality, and voluntary nature of participation. Participants were informed of their right to withdraw from the study at any time without penalty. Participant anonymity and confidentiality were maintained throughout data collection, analysis, and reporting. Appropriate safety precautions were implemented during physiotherapy and WB-EMS sessions, and participants were monitored throughout the intervention. The study was conducted in accordance with the principles of the Declaration of Helsinki and applicable institutional ethical guidelines.



6. RESULTS

Table 3: Socio demographic Characteristics of Participants

Variable	Category	CPT (Control) n (%)	WB-EMS (Intervention) n (%)
Gender	Male	6 (25.0%)	9 (37.5%)
	Female	18 (75.0%)	15 (62.5%)

	Total	24 (100.0%)	24 (100.0%)
Education	Secondary/High School	5 (20.8%)	4 (16.7%)
	Intermediate/Diploma	6 (25.0%)	5 (20.8%)
	Bachelor's Degree	9 (37.5%)	10 (41.7%)
	Master's Degree or Above	4 (16.7%)	5 (20.8%)
Income	Low Income	7 (29.2%)	6 (25.0%)
	Lower-Middle Income	8 (33.3%)	9 (37.5%)
	Middle Income	6 (25.0%)	7 (29.2%)
	Higher Income	3 (12.5%)	2 (8.3%)

Note: Values are presented as frequency and percentage, n (%). Each group consisted of 24 participants.

Table 3 shows that females constituted the majority of participants in both groups, accounting for 75.0% in the CPT group and 62.5% in the WB-EMS group, while males represented 25.0% and 37.5%, respectively. Regarding education, most participants in both

groups had a Bachelor's degree (37.5% in CPT and 41.7% in WB-EMS). In terms of income, the lower-middle-income category was most common in both groups (33.3% in CPT and 37.5% in WB-EMS). Overall, the sociodemographic characteristics of the two groups were broadly comparable.

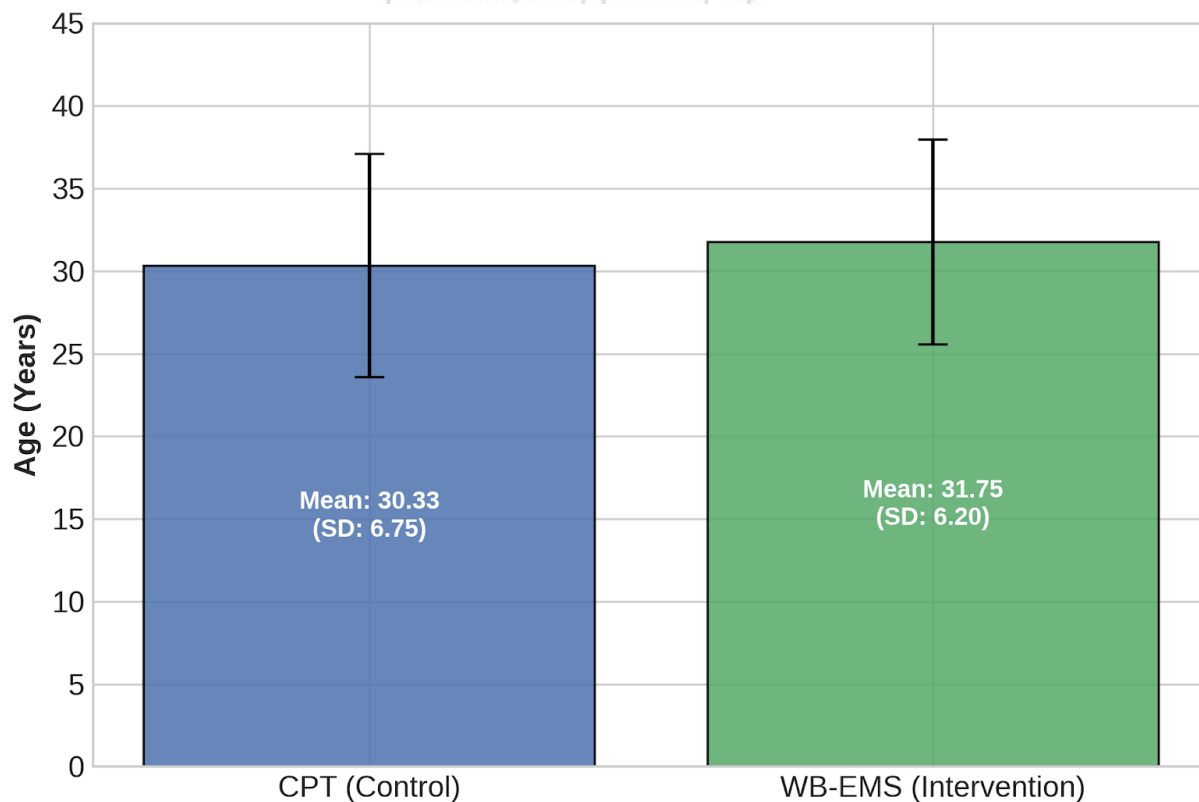


Figure 1 Mean age and standard deviation of participants in the CPT (Control) and WB-EMS (Intervention) groups.

Figure 1 illustrates the mean age of participants in the two study groups. The average age was 30.33 ± 6.75 years in the CPT group and 31.75 ± 6.20 years in the WB-EMS group. The findings indicate that the mean ages of participants in both groups were comparable, with only a small difference between the groups.

Table 4: Pre- and Post-Intervention Assessment of Pain, Disability, and Core Endurance

Outcome Measure	CPT Pre (Mean $\pm$ SD)	CPT Post (Mean $\pm$ SD)	WB-EMS Pre (Mean $\pm$ SD)	WB-EMS Post (Mean $\pm$ SD)
NPRS (Pain Intensity)	6.67 ± 1.55	5.25 ± 1.54	6.92 ± 1.38	4.00 ± 1.50
ODI (%) (Functional Disability)	59.92 ± 4.43	50.25 ± 5.05	58.08 ± 3.93	28.17 ± 5.34
Flexor Endurance Test (s)	59.00 ± 14.69	67.91 ± 15.31	63.75 ± 14.08	87.45 ± 13.32
Extensor Endurance Test (s)	75.58 ± 13.00	84.50 ± 12.43	76.41 ± 13.52	105.58 ± 13.19
Left Side Bridge Test (s)	50.50 ± 15.87	60.08 ± 14.95	55.66 ± 13.55	72.16 ± 14.35
Right Side Bridge Test (s)	58.37 ± 14.64	66.20 ± 14.49	53.41 ± 14.18	68.83 ± 14.40
Flexor-Extensor Ratio	0.79 ± 0.21	0.82 ± 0.20	0.86 ± 0.27	0.84 ± 0.17
Side-Extensor Ratio	0.73 ± 0.17	0.76 ± 0.15	0.73 ± 0.19	0.67 ± 0.12
Right-to-Left Side Bridge Ratio	1.27 ± 0.49	1.17 ± 0.37	1.03 ± 0.45	1.00 ± 0.34

Note: NPRS = Numeric Pain Rating Scale; ODI = Oswestry Disability Index; s = seconds. Values are presented as Mean $\pm$ Standard Deviation. Lower NPRS and ODI scores indicate less pain and disability, respectively, whereas longer endurance-test times indicate better trunk muscle endurance. Ratios are presented to describe the relative balance of trunk muscle endurance.

Table 4 demonstrates improvement in all major outcome measures following the intervention in both groups. Pain intensity decreased from 6.67 ± 1.55 to 5.25 ± 1.54 in the CPT group and from 6.92 ± 1.38 to 4.00 ± 1.50 in the WB-EMS group. Similarly, functional disability measured by ODI decreased from $59.92 \pm 4.43\%$ to $50.25 \pm 5.05\%$ in the CPT group and from $58.08 \pm 3.93\%$ to $28.17 \pm 5.34\%$ in the WB-EMS group, indicating a greater reduction in disability with WB-EMS. Trunk flexor, extensor, and side-bridge endurance also improved in both groups, with greater increases generally observed in the WB-EMS group. The core endurance ratios showed relatively small changes, with the WB-EMS group demonstrating an improvement in the side-to-extensor ratio and right-to-left side-bridge balance. Overall, the findings indicate that both interventions improved pain, functional disability, and trunk muscle endurance, while the WB-EMS group showed greater overall improvements, particularly in pain, disability, and muscular endurance.

Table 5: Categorical Assessment of Pain, Disability, and Core Muscle Balance Before and After Intervention

Outcome Measure	Category	CPT Pre n (%)	CPT Post n (%)	WB-EMS Pre n (%)	WB-EMS Post n (%)
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Pain Intensity (NPRS)	Mild	0 (0.0%)	2 (8.3%)	0 (0.0%)	11 (45.8%)
	Moderate	11 (45.8%)	16 (66.7%)	9 (37.5%)	12 (50.0%)
	Severe	13 (54.2%)	6 (25.0%)	15 (62.5%)	1 (4.2%)
ODI Disability	Minimal disability	0 (0.0%)	0 (0.0%)	0 (0.0%)	4 (16.7%)
	Moderate disability	0 (0.0%)	1 (4.2%)	0 (0.0%)	20 (83.3%)
	Severe disability	18 (75.0%)	22 (91.7%)	20 (83.3%)	0 (0.0%)
	Crippled	6 (25.0%)	1 (4.2%)	4 (16.7%)	0 (0.0%)
	Bedridden/exaggerating symptoms	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Flexor-Extensor Ratio	Poor (≥ 1.0)	5 (20.8%)	6 (25.0%)	7 (29.2%)	5 (20.8%)
	Good (< 1.0)	19 (79.2%)	18 (75.0%)	17 (70.8%)	19 (79.2%)
Side-Extensor Ratio	Poor (≥ 0.75)	9 (37.5%)	11 (45.8%)	10 (41.7%)	7 (29.2%)
	Good (< 0.75)	15 (62.5%)	13 (54.2%)	14 (58.3%)	17 (70.8%)
Right-to-Left Side-Bridge Ratio	Poor	24 (100.0%)	23 (95.8%)	20 (83.3%)	23 (95.8%)
	Good (difference < 0.05)	0 (0.0%)	1 (4.2%)	4 (16.7%)	1 (4.2%)

Note: Values are presented as frequency and percentage, n (%). NPRS = Numeric Pain Rating Scale; ODI = Oswestry

Disability Index. NPRS categories: mild = 1–3, moderate = 4–6, severe = 7–10. ODI categories: minimal = 0–20%, moderate = 21–40%, severe = 41–60%, crippled = 61–80%, and bedridden/exaggerating symptoms = 81–100%.

Table 5 indicates improvement in pain intensity, functional disability, and core muscle balance following treatment in both groups. The WB-EMS group demonstrated greater improvement, with severe pain decreasing from 62.5% to 4.2% and participants shifting from severe/crippled disability to mainly moderate disability. The CPT group also showed a reduction in severe pain and crippled disability, although improvement was less pronounced. Core endurance classifications showed improvement particularly in the side-extensor ratio in the WB-EMS group, while changes in the flexor-extensor and right-to-left side-bridge ratios were relatively limited. Overall, the categorical findings favor WB-EMS as a more effective adjunct to conventional physiotherapy for improving pain, disability, and selected aspects of core muscle balance.

Table 6 Test of Normality (Shapiro-Wilk Test)

Variable	CPT <i>p</i>	WB-EMS <i>p</i>
NPRS Pre	0.002	0.024
NPRS Post	0.016	0.196
ODI Pre	0.024	0.109
ODI Post	0.481	0.181
Flexor Endurance Pre	0.077	0.183
Flexor Endurance Post	0.035	0.723
Extensor Endurance Pre	0.429	0.010
Extensor Endurance Post	0.363	0.550
Left Side Bridge Pre	0.019	0.113
Left Side Bridge Post	0.057	0.586
Right Side Bridge Pre	0.062	0.229
Right Side Bridge Post	0.222	0.465

Note: Shapiro–Wilk test; $p > 0.05$ indicates normal distribution and $p < 0.05$ indicates non-normal distribution.

Table 7: Within-Group Comparison of Outcomes Before and After Intervention

Outcome Measure	Group	Pre-intervention Mean $\pm$ SD	Post-intervention Mean $\pm$ SD	Z value	p-value
NPRS	CPT (Control)	6.67 $\pm$ 1.55	5.25 $\pm$ 1.54	-4.428	<0.001
	WB-EMS (Intervention)	6.92 $\pm$ 1.38	4.00 $\pm$ 1.50	-4.344	<0.001
ODI (%)	CPT (Control)	59.92 $\pm$ 4.43	50.25 $\pm$ 5.05	-4.304	<0.001
	WB-EMS (Intervention)	58.08 $\pm$ 3.93	28.17 $\pm$ 5.34	-4.304	<0.001
Flexor Endurance (sec)	CPT (Control)	59.00 $\pm$ 14.69	67.91 $\pm$ 15.31	-4.296	<0.001
	WB-EMS (Intervention)	63.75 $\pm$ 14.08	87.45 $\pm$ 13.32	-4.290	<0.001
Extensor Endurance (sec)	CPT (Control)	75.58 $\pm$ 13.00	84.50 $\pm$ 12.43	-4.292	<0.001
	WB-EMS (Intervention)	76.41 $\pm$ 13.52	105.58 $\pm$ 13.19	-4.288	<0.001
Left Side Bridge (sec)	CPT (Control)	50.50 $\pm$ 15.87	60.08 $\pm$ 14.95	-4.311	<0.001
	WB-EMS (Intervention)	55.66 $\pm$ 13.55	72.16 $\pm$ 14.35	-4.291	<0.001

Right Side Bridge (sec)	CPT (Control)	58.37 ± 14.64	66.20 ± 14.49	-4.302	<0.001
	WB-EMS (Intervention)	53.41 ± 14.18	68.83 ± 14.40	-4.295	<0.001

Note: Wilcoxon signed-rank test was used for within-group comparisons. $p < 0.05$ was considered statistically significant.

Table 7 showed within-group analysis statistically significant improvements in all assessed outcomes following the intervention in both groups ($p < 0.001$). NPRS and ODI scores decreased in both the CPT and WB-EMS groups, indicating reduced pain intensity and functional disability. In contrast, flexor, extensor, left-side bridge, and

right-side bridge endurance times increased significantly, demonstrating improved trunk and core muscle endurance. Overall, both interventions produced significant pre- to post-intervention improvements; however, the magnitude of improvement was greater in the WB-EMS group for most outcomes.

Table 8: Between-Group Comparison of Outcome Measures

Outcome Measure	CPT Pre Mean ± SD	CPT Post Mean ± SD	WB-EMS Pre Mean ± SD	WB-EMS Post Mean ± SD	Z value	p-value
NPRS	6.67 ± 1.55	5.25 ± 1.54	6.92 ± 1.38	4.00 ± 1.50	-2.561	0.010
ODI (%)	59.92 ± 4.43	50.25 ± 5.05	58.08 ± 3.93	28.17 ± 5.34	-5.965*	<0.001*
Flexor Endurance (sec)	59.00 ± 14.69	67.91 ± 15.31	63.75 ± 14.08	87.45 ± 13.32	-3.807	<0.001
Extensor Endurance (sec)	75.58 ± 13.00	84.50 ± 12.43	76.41 ± 13.52	105.58 ± 13.19	-4.529	<0.001
Left Side Bridge (sec)	50.50 ± 15.87	60.08 ± 14.95	55.66 ± 13.55	72.16 ± 14.35	-2.569	0.010
Right Side Bridge (sec)	58.37 ± 14.64	66.20 ± 14.49	53.41 ± 14.18	68.83 ± 14.40	-0.588	0.557

Note: Between-group comparisons were performed using the Mann–Whitney U test on post-intervention scores, except for ODI, for which change scores (Post – Pre) were analyzed using the Mann–Whitney U test.

Table 7 showed between-group analysis statistically significant differences in post-intervention outcomes for NPRS, ODI, flexor endurance, extensor endurance, and left-side bridge endurance ($p \leq 0.010$). The WB-EMS group demonstrated lower post-intervention pain and disability scores and greater improvements in flexor, extensor, and left-side bridge endurance

compared with the CPT group. However, no statistically significant difference was found between groups for the right-side bridge test ($p = 0.557$). Overall, the findings indicate that WB-EMS combined with conventional physiotherapy produced greater improvements in pain, disability, and most measures of core muscle endurance than conventional physiotherapy alone.

7. DISCUSSION

The present randomised controlled trial compared conventional physiotherapy (CPT) alone with CPT combined with whole-body electromyostimulation (WB-EMS) for pain, functional disability, and trunk muscle endurance in individuals with chronic low back pain (CLBP). Both groups demonstrated significant improvements following the 12-week intervention; however, the WB-EMS group achieved greater improvements in pain intensity, disability, flexor endurance, extensor endurance, and left-side bridge endurance. Right-side bridge endurance improved within both groups, but the between-group difference was not significant.

The demographic characteristics of the groups were broadly comparable, with a mean age of approximately 30 years and a higher proportion of female participants. This is consistent with Nicol et al. [34], who identified CLBP as a common condition among adults, with potentially greater prevalence among females. The overall comparability of baseline characteristics supports the validity of the subsequent group comparisons. Pain intensity decreased significantly in both groups, with a significantly greater reduction in NPRS scores in the WB-EMS group ($p = 0.010$). This finding is consistent with Konrad et al. [35], who reported clinically meaningful reductions in pain following WB-EMS in individuals with chronic non-specific low back pain. The additional benefit observed in the present study may reflect the combined effects of therapeutic exercise and electrical stimulation, potentially enhancing neuromuscular activation and trunk muscle recruitment. Improved muscular control may contribute to greater spinal stability and reduced mechanical stress during movement, although these proposed mechanisms should be interpreted cautiously.

Similarly, both groups demonstrated significant improvements in ODI scores, with a substantially greater reduction in disability in the WB-EMS group ($p < 0.001$). These findings are consistent with Kemmler et al. [36], who reported improvements in physical function and muscular

performance following WB-EMS. The superior functional improvement observed in the present study may partly reflect the reduction in pain alongside enhanced trunk muscle capacity, enabling participants to perform daily activities with fewer functional limitations. The categorical ODI findings further support this interpretation, particularly in the WB-EMS group, where disability shifted from more severe categories towards moderate and minimal disability. Cardozo-Batista et al. [37] similarly emphasised the potential importance of neuromuscular rehabilitation in improving functional outcomes in persistent low back pain.

Trunk muscle endurance also improved significantly following treatment. Flexor and extensor endurance showed significantly greater post-intervention performance in the WB-EMS group (both $p < 0.001$). These findings are consistent with previous evidence demonstrating improvements in muscular performance following WB-EMS [36,38]. The additional electrical stimulus may have enhanced motor-unit recruitment alongside active exercise, thereby providing a greater training stimulus to the abdominal and lumbar musculature. Improved extensor endurance may also contribute to sustained spinal support and postural control during functional activities.

Left-side bridge endurance was significantly greater following WB-EMS ($p = 0.010$), supporting previous findings of improved trunk muscular performance following WB-EMS [39]. This improvement may reflect enhanced conditioning of the lateral trunk musculature involved in maintaining pelvic and spinal stability. However, the proposed muscle-specific mechanisms should be interpreted cautiously because the present study did not directly assess individual muscle activation.

In contrast, right-side bridge endurance improved significantly within both groups, but the between-group difference was not significant ($p = 0.557$). Thus, although both interventions were associated with improved right-sided endurance, the present findings do not demonstrate an additional benefit

of WB-EMS for this outcome. The asymmetry between the left- and right-sided findings may reflect individual differences in muscle dominance, baseline muscular characteristics, or variability in response to training. It also illustrates that the effects of WB-EMS may not be uniform across all dimensions of trunk performance. Similar variability across outcome measures has been reported in previous WB-EMS research [39]. Overall, the findings support the potential value of incorporating WB-EMS into conventional physiotherapy for CLBP. The greater improvements in pain, disability, and several measures of trunk endurance suggest that WB-EMS may provide an additional therapeutic stimulus beyond conventional rehabilitation alone. Nevertheless, the non-significant difference in right-side bridge endurance indicates that this additional effect is not consistent across all measures of trunk performance. The findings therefore support WB-EMS as a potentially useful adjunct rather than establishing it as universally superior to conventional physiotherapy.

The study has several strengths, including its randomised controlled design, standardised intervention protocol, and use of established outcome measures, including NPRS, ODI, and McGill trunk endurance tests. Statistical analyses were selected according to data distribution, with non-parametric procedures used where appropriate. However, several limitations should be acknowledged. The relatively small sample size and recruitment from a limited clinical setting may restrict generalisability, while the absence of long-term follow-up prevents conclusions regarding the persistence of treatment effects. Psychological factors and quality of life were also not assessed. Future research should therefore employ larger and more diverse samples, longer follow-up periods, and broader functional and psychosocial outcomes to determine the durability and clinical relevance of WB-EMS as an adjunct to conventional physiotherapy for CLBP.

8. CONCLUSION

The present study concluded that both conventional physiotherapy (CPT) and WB-EMS combined with CPT significantly improved pain, functional disability, and core muscle endurance in individuals with chronic low back pain. However, the addition of WB-EMS produced significantly greater improvements in pain reduction, disability, flexor endurance, extensor endurance, and left-side bridge endurance compared with CPT alone. No significant between-group difference was observed for right-side bridge endurance. Therefore, WB-EMS combined with conventional physiotherapy may be considered a beneficial adjunctive treatment for improving clinical and functional outcomes in individuals with chronic low back pain.

9. LIMITATIONS

- The sample size was relatively small, which may limit the generalizability of the findings.
- Participants were recruited from a single clinical setting, limiting applicability to other populations and healthcare settings.
- The intervention lasted only 12 weeks, and no long-term follow-up was conducted.
- The study focused on pain, disability, and core muscle endurance; quality of life, psychological factors, and treatment satisfaction were not assessed.

10. RECOMMENDATIONS

- ✓ Future studies should include larger and more diverse samples recruited from multiple healthcare centers.
- ✓ Long-term follow-up studies are recommended to determine the sustainability of WB-EMS-related improvements.
- ✓ Future research should assess additional outcomes, including quality of life, psychological well-being, treatment satisfaction, and return to daily activities.
- ✓ Further studies should compare different WB-EMS protocols, treatment frequencies, durations, and patient populations to

determine the most effective approach for chronic low back pain.

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