Research Paper

Impact of Movement Pattern Training on Muscular Co-contraction in Patients With Low Back Pain During Walking

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ABSTRACT

Purpose: Low back pain (LBP) is a health problem. Rehabilitation could be a suitable therapy for LBP patients. Nonetheless, the effectiveness of movement pattern training on LBP patients has not been assessed scientifically. So, this research examined the effects of movement pattern exercise on general lower limb muscular co-contraction in patients with non-specific chronic LBP during walking.

Methods: The current research was quasi-experimental. Forty male adults who experienced non-specific chronic LBP voluntarily enrolled in this study. Twenty samples were assigned in the intervention group and 20 in the control group. The exercise protocol used in this study was based on the Harris-Hayes et al. protocol, which takes 18 supervised training sessions (during 6 weeks). The assessments were conducted before the intervention and again after 6 weeks. General co-contraction of the lower limb muscles was recorded using electromyography while walking, and the total activation of the muscles that abounded the joint was calculated.

Results: The findings indicate a significant decrease in general co-contraction of the ankle in the intervention group at propulsion ($P=0.011$, $\eta^2=0.160$). Also, the results show that at the loading phase, general knee co-contraction is greater in the experimental group compared with the control group ($P=0.037$, $\eta^2=0.110$).

Conclusion: Our research reveals that the training program improves the general co-contraction of the lower limb muscles in individuals with LBP.

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Highlights

• Movement pattern training significantly reduces general ankle co-contraction in patients with chronic low back pain during the push-off phase, indicating improved neuromuscular control during walking.

• The study included 30 male adults with low back pain, providing valuable insights into the effects of special training on gait abnormalities in this population.

• Movement pattern training may be a valuable intervention for improving functional outcomes and addressing gait abnormalities in patients with chronic lower back pain.

Plain Language Summary

Low back pain (LBP) is a common problem experienced by older people—affecting around 84% of these people. LBP is associated with alterations in gait mechanics, and there is a relationship between mechanical irregularities in the lower extremities and lumbar region. Also, the co-contraction of knee muscles serves as a mechanism for modifying joint stability and loading. Individuals with LBP may exhibit altered co-contraction of lower limb muscles during walking. This research investigates the impact of movement pattern training on general lower limb muscular co-contraction in patients with non-specific chronic LBP. Results showed that general knee co-contraction was significantly greater at loading after training. Findings showed a significant effect of the "Group" for general co-contraction of the knee during loading response (P=0.037, d= 0.110) and push-off (P=0.011 d= 0.160) phases. Also, the "Group*Time" effect was not significant for general lower limb co-contraction during gait (P>0.05). Our findings demonstrate that the training protocol affects lower limb muscular co-contraction in individuals with LBP.

Introduction

Low back pain (LBP) occurs in about 80% of people in their lifetime [1]. In 2015, approximately 7.3% of the population worldwide experienced activity limitations due to LBP [2]. LBP begins at 20 and 40 [2], with a high prevalence observed between 30 and 60 [3]. As a result, LBP is a common health problem that primary care settings frequently encounter [4]. LBP is associated with alterations in walking mechanics [3]. Excess foot pronation during the loading phase of walking can cause disrupted lower limb alignments and, ultimately LBP [5]. The trunk has been conceptualized as a pendulum [6]. As a result, the trunk-lower limb system is essential for the spine as a kinematic chain. This system consists of several parts and joints affecting the lumbar area and lower limb interaction while moving. Any dysfunction impacting this complex can disturb this connection, resulting in atypical motion. Different walking problems, like shorter steps and stiff coordination between body sections, are observed in people suffering from LBP [7].

The co-contraction of knee muscles is a mechanism for modifying joint stability and loading [8]. Individuals with LBP may show changed simultaneous contraction of lower limb muscles when walking. Generalized co-contraction is the simultaneous activation of all knee muscle groups [9]. Wang et al. reported that patients with lumbar disk herniation show enhanced biceps femoris root mean square at the stance phase. Positive relationships have been reported between tibialis anterior and gastrocnemius co-contraction and the disability index [10].

One common complication of this condition can be altered movement patterns during walking, leading to increased co-contraction of knee and ankle muscles [11]. Despite existing interventions, such as movement pattern training, the impact of these interventions on reducing knee and ankle muscular co-contraction in patients with non-specific chronic LBP (NSCLBP) during walking remains poorly understood. Movement pattern training is a therapeutic exercise that improves movement quality, coordination, and efficiency [12]. The training involves specific exercises and techniques designed to retrain and optimize movement patterns to enhance functional performance and reduce the risk of injury [13]. Movement pattern training addresses faulty movement patterns, postural imbalances, muscle imbalances, and improper biomechanics to help individuals move more effectively and efficiently [14]. This type of training can be beneficial for improving sports performance, rehabilitation from injuries, and enhancing overall movement quality in daily activities [14]. However, there is a need to assess the effect of movement pattern exercises in addressing this specific issue to improve the management and outcomes of NSCLBP. Therefore, this study aims to investigate the impact of movement pattern training on general lower limb muscular co-contraction at walking in patients with NSCLBP.

Materials and Methods

Study design and participants

This research was conducted with the ethical code of IR.SBU.REC.1399.060), and registration number of IRCT20181024041444N1. Informed consent was received from all samples. The study recruited 40 male patients with LBP from local clinics. The G*power software, version 3.1.9.7, was used to estimate the required sample size [15]. The software determined that at least 40 participants would be needed. The subjects were divided into intervention (EG, n=20) and control (CG, n=20) groups. The inclusion criteria were as follows: Pain persisting >3 months, visual analog scale >3 cm, and disability index of >10 [16]. The exclusion criteria were as follows: LBP of traumatic origin, history of surgery, and musculoskeletal misalignments [17].

The eligible participants were allocated into both groups using the block randomization method [18].

Training protocol

The exercise protocol used in this study was based on that introduced by Harris-Hayes et al. [19]. All the participants belonging to the EG underwent a total of 18 training sessions for 6 weeks. The movement pattern training program incorporated two primary components: Task-specific exercise (e.g. based on walking) for specific tasks and hip musculature strengthening.

Participants were instructed to start with a minimum number of exercise repetitions, gradually increasing as tolerated, ensuring correct execution and the absence of hip pain. At each visit, a therapist evaluated the performance of specific functional tasks and strength exercises, focusing on mastery for autonomous practice. Functional independence required patients to replicate modified lower limb movements accurately. Once achieved, no further guidance was issued, but patients were advised to maintain these patterns in daily activities. Symptom-inducing tasks were addressed in the first session, with subsequent instruction in later sessions. Strength exercise independence demanded precise execution and muscle engagement, progressing to higher resistance via altered body positioning or elastic bands upon achieving two sets of 20 repetitions [19]. The CG group received no treatment. The movement pattern training was divided into levels 1-3 without resistance to the band and 4-5 with band resistance. The training in the first week includes familiarization with the training protocols. From weeks 2 to 5, including week 2, the strength training for the hip external rotator at extension is implemented. In week 3, the strength training for the hip external rotator with the hip in flexion started. In week 4, hip flexor strengthening exercises are practiced. Week 5 includes hip abductor strengthening, and in week 6, the participants practiced strength training for the hip external rotator and abductor. The intervention group performed 18 exercise sessions over 6 weeks.

Co-contraction

All subjects walked along an 18-m path before and after training. Ag/AgCl electrodes were used to record the activities of tibialis anterior (TA), gastrocnemius medialis (Gas-M), biceps femoris (BF), semitendinosus (ST), vastus lateralis (VL), vastus medialis (VM), rectus femoris (RF) of the dominant limb [8]. The sample rate was 1000 Hz using an EMG system (Biometrics Ltd, UK) [5]. The root mean square (RMS) data were calculated at loading, mid-stance, and push-off sub-phases [20-22]. Maximum voluntary isometric contraction was applied to normalize EMG amplitude [23].

The general co-contraction was calculated using the Equation 1 [24]:

1. General ankle co-contraction=Tibialis anterior+Gastrocnemius medialis

General knee co-contraction=Sum of all agonist and antagonist mean EMG activities [25].

The stance phase was determined using a Bertec force plate (USA) with a 10 N vertical force threshold.

Statistical analysis

We utilized the G*Power freeware tool to estimate the sample size [26]. The data normality was confirmed by the Shapiro-Wilk test. A two-way ANOVA with repeated measures was applied in the statistical section. Eta-squared (η^2) was used to calculate effect size [27]. The α level was set at 0.05.

Table 1. Anthropometric features of both groups

Demographics	Mean±SD		P
	Experimental Group	Control Group	
Age (y)	26.40±4.46	26.2±4.3	0.911
Height (m)	1.61±9.38	1.68±7.64	0.952
Weight (kg)	77.20±10.92	72.58±9.30	0.495
Visual analog scale	6.1±0.8	6.2±0.6	0.852
Disability index	13.1±0.9	13.3±1.1	0.951

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Results

Results of baseline data

All subjects received their assigned treatment as planned, and the adherence rate for both groups was 100% (Table 1).

No differences were found for baseline knee and ankle general co-contraction values (P>0.05) (Table 2).

Results of co-contraction data

The main effect of "Group" for general co-contraction of the ankle was significant during push off phase (P=0.011, η^2=0.160). Results revealed greater general co-contraction of the ankle at propulsion in the control group than in the experimental group (Table 3).

Effects of "Time" for general co-contraction of the knee was significant during loading phase (P=0.001, η^2=0.246). Greater general co-contraction of the knee at loading after training was observed compared to before training. Findings showed greater general co-contraction of the knee at the loading phase in the experimental group than in the control group (P>0.05) (Table 4).

Discussion

This research assesses the impact of movement pattern training on general knee and ankle muscular co-contraction during walking in NSCLBP patients. The findings indicate a significant decrease in general co-contraction of the ankle at propulsion. Instead, they work in synergy to position the foot correctly in preparation for the next heel strike [28]. The occurrence of TA/GL co-contraction throughout the posture has been reported in numerous studies [29, 30]. Also, our study did not show a significant effect for general ankle co-contraction at the mid-stance phase during walking. The recruitment of the TA during this phase is not associated with ankle dorsiflexion but rather with its activation as a foot-invertor muscle. Consequently, the TA and GL muscles do not function antagonistically but rather engage in co-contraction to maintain balance [31], as sup-

Table 2. General co-contraction values in both groups

Characteristics	Phase	Before Training		P
		Experimental Group	Control Group	
General ankle co-contraction	Loading	61.99±7.86	63.17±17.97	0.81
	Mid-stance	30.44±7.03	33.54±5.72	0.19
	Push-off	44.43±7.26	41.44±6.87	0.25
General knee co-contraction	Loading	101.62±47.67	88.22±18.88	0.25
	Mid-stance	91.01±18.09	99.76±38.65	0.36
	Push-off	78.92±16.90	88.18±27.37	0.16

Data are presented as Mean±SD.

Table 3. General ankle co-contraction

Phase	Preintervention		Postintervention		Sig. (Effect Size)		
	Control	Experimental	Control	Experimental	Main Effect, Time	Main Effect, Group	Interaction: Time × Group
Loading response	61.99±7.86	63.17±17.97	60.91±7.98	58.38±15.56	0.380 (0.020)	0.797 (0.002)	0.574 (0.008)
Mid stance	30.44±7.03	33.54±5.72	34.02±10.52	32.70±7.09	0.419 (0.017)	0.626 (0.006)	0.195 (0.034)
Push-off	44.43±7.26	41.44±6.87	43.00±7.05	37.05±6.62	0.051 (0.096)	0.011* (0.160)	0.312 (0.027)

Data are presented as Mean±SD; *P<0.05.

PHYSICAL TREATMENTS

Table 4. General knee co-contraction

Phase	Before Training		After Training		Sig. (Effect Size)		
	Control Group	Experimental Group	Control Group	Experimental Group	Main Effect, Time	Main Effect, Group	Interaction: Time × Group
Loading	101.62±47.67	88.22±18.88	113.59±23.76	137.81±31.74	0.001* (0.246)	0.015* (0.146)	0.683 (0.006)
Mid stance	91.01±18.09	99.76±38.65	101.13±29.01	101.38±30.56	0.250 (0.035)	0.601 (0.007)	0.376 (0.021)
Push-off	78.92±16.90	88.18±27.37	73.37±28.87	80.89±24.31	0.187 (0.045)	0.820 (0.001)	0.092 (0.073)

Data are presented as Mean±SD; *P<0.05.

PHYSICAL TREATMENTS

ported by Di Nardo's study, which reported smaller-level co-contractions [32]. Therefore, the decrease in general ankle co-contraction at the propulsion could suggest that movement pattern training may positively impact the efficiency and coordination of walking in patients with non-specific chronic LBP [33].

Additionally, the study revealed significant changes in general co-contraction of the knee at the loading. The increase in knee co-contraction at the loading in the intervention group suggests that the movement pattern training intervention had a specific effect on knee muscle activation patterns during the initial phase of walking. This condition could indicate improved neuromuscular control, joint stability, or functional coordination at the knee joint following the intervention [34]. Furthermore, the differences between the experimental and control groups highlight the potential benefits of targeted movement pattern training in addressing gait abnormalities and muscle co-contraction patterns in individuals with LBP. The results suggest that focusing on specific movement patterns can alter muscle activation strategies during gait, potentially improving movement efficiency and reducing compensatory mechanisms that may contribute to pain and dysfunction [35]. Also, previous research has identified knee joint instability as contributing to falls in individuals. The heightened general contractility in the knee joint may be linked to joint stability. Consequently, increasing general knee co-contraction may serve as a core strategy for enhancing joint stability during walking [36].

Conclusion

Our training protocol affects the general co-contraction of the lower limb muscles in patients with LBP. The increased co-contraction of the knee during the loading in the intervention group could indicate improved neuromuscular control, joint stability, or functional coordination at the knee joint following the intervention. Also, focusing on specific movement patterns can lead to alterations in muscle activation strategies during gait, potentially improving movement efficiency and reducing compensatory mechanisms that may contribute to pain and dysfunction.

Limitations

We evaluated only male participants, highlighting a gap that future research should aim to fill by exploring the effects of similar training protocols on female populations, who may exhibit different biomechanical and physiological responses to movement pattern training.

Ethical Considerations

Compliance with ethical guidelines

This research was conducted with the ethical code of IR.SBU.REC.1399.060 and registration number of IRCT20181024041444N1. Informed consent was received from all samples.

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Authors' contributions

Conceptualization, Supervision, and Writing the original draft: AmirAli Jafarnezhadgero and Ehsan Fakhri Mirzanag; Methodology and Statistics analysis: Ehsan Fakhri Mirzanag and Milad Piran Hamlabadi; Investigation and Data collection: Afshiin Orouji, Amir Letafatkar, and Milad Piran Hamlabadi; Review and editing: All authors.

Conflict of interest

The authors declared no conflict of interest.

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