RESEARCH ARTICLE

Effects of External Focus and Motor Control Training in Comparison with Motor Control Training Alone on Pain, Thickness of Trunk Muscles and Function of Patients with Recurrent Low Back Pain: A Single Blinded, Randomized Controlled Trial

Hamid Zamani, PhD, PT[1]; Mahdi Dadgoo, PhD, PT[1]; Mohammad Akbari, PhD, PT[1]; Javad Sarrafzadeh, PhD, PT[1]; Mohammadreza Pourahmadi, PhD, PT[1]

Research performed at the Biomechanics Laboratory, School of Rehabilitation Sciences, Iran University of Medical Sciences, Tehran, Iran

Received: 12 April 2021 *Accepted: 22 February 2022*

Abstract

Background: Recurrent low back pain (RLBP) affects different structures in the lumbar spine. Exercise therapy is highly recommended as one of the first-line treatments. One crucial variable introduced to enhance RLBP is the external focus. The present study aimed to investigate the effects of external focus training on pain, the thickness of transverse abdominis (TrA), internal oblique (IO), external oblique (EO), and lumbar multifidus (LM) muscles, kinesiophobia, fear-avoidance beliefs, and disability of people with RLBP.

Methods: This randomized-controlled trial consisted of 38 RLBP patients. Patients were randomly divided into two groups the treatment group (n=19) that received external focus training in addition to motor control training and the control group (n=19) that received motor control training alone. The primary outcome was pain intensity, and secondary outcomes were the thickness of TrA, IO, EO, LM muscles, kinesiophobia, fear-avoidance beliefs, and disability that were measured at the baseline and after 16 sessions of interventions. The interventions were performed three sessions weekly.

Results: Reduction in pain intensity was more significant in the intervention group than in the control group (*P<0.001*, Cohen's *d*=-1.47). The thickness of TrA muscle in the contraction condition of the intervention group was significantly more on the left side (*P<0.001*, Cohen's *d*=1.05) than on the right side (*P=0.03*, Cohen's *d*=0.44). Other outcomes showed no significant differences. However, the Cohen's *d* effect size for the left IO (Cohen's *d*=0.57) and TKS (Cohen's *d*=-0.53) were moderate.

Conclusion: In RLBP patients, external focus and motor control training could effectively reduce the pain. Although this intervention could increase the thickness of the TrA muscle of RLBP, it has no significant effect on the thickness of IO, EO, and LM muscles. In addition, the obtained results indicated that this intervention has no significant effect on kinesiophobia, fear-avoidance beliefs, and disability..

Level of evidence: I

Keywords: Abdominal muscle, Disability, Exercise therapy, Lumbar region, Recurrent low back pain

Introduction

Low back pain (LBP) is a complicated problem that may affect bio-psychosocial aspects of an individual's life. It has been regarded as the greatest contributor to disability worldwide.[1] It is estimated that about 84% of people may develop LBP during their lifetime, and about 12% of them suffer from disability due to that.[2]

Corresponding Author: Mahdi Dadgoo, Rehabilitation Research Center, Department of Physiotherapy, School of Rehabilitation Sciences, Iran University of Medical Sciences, Tehran, Iran
Email: dadgoo.m@iums.ac.ir

THE ONLINE VERSION OF THIS ARTICLE ABJS.MUMS.AC.IR

Statistics have reported that in recent decades, the largest increase in LBP disability has been in low- and middle-income countries in Asia, Africa, and the Middle East.[3] No specific cause or pathology is found in more than 90% of LBP patients; this group is known as non-specific.[4] Most people with acute LBP recover without any problem; however, some are at risk of recurrent low back pain (RLBP). Previous studies have shown that the probability of RLBP is 22.1% at three months and 77.1% at three years after the recovery from an acute LBP period.[5]

There are several factors involved in the RLBP development. Even many non-musculoskeletal factors may also contribute to RLBP.[6] One of the most important factors is the change of motor control in deep trunk muscles. Especially, delay in the onset of transverse abdominis muscle (TrA) background activity is accompanied by movements of the upper extremities.[7] The neuromuscular system of RLBP patients may adopt a compensatory movement program in the joints associated with the spine.[8]

Motor control training has been among the most popular treatments for RLBP that has been recommended by clinical practice guidelines of the orthopedic branch of the American Physiotherapy Association.[9,10] Because it has been proven that if abnormal changes in muscle recruitment do not improve, patients who have recovered from a period of LBP are more likely to develop RLBP.[11]

One of the crucial topics that has been studied recently in exercise therapy is the external focus. External focus includes instructions that direct a patient's attention to something in the environment and out of their own body (e.g., an external target). In contrast, when a person's attention is on a part of the body (e.g., a specific muscle or joint), it is considered an internal focus.[12] Studies suggested that internal focus may interfere with the automatic motor control process. In contrast, the external focus could provide a more automatic process to select and control the movements.[13] So far, only the immediate effects of external focus have been studied, and its effect as an intervention on RLBP has not been examined. Cross-sectional studies have shown that external focus training could improve the function of some trunk muscles.[14]

Furthermore, according to the review studies that have examined the effects of external focus on musculoskeletal disorders, external focus training effectively improves motor function, the durability of exercise results, and facilitates the function of patients with musculoskeletal disorders.[15] Considering the mentioned advantages in previous studies for the external focus trainings, its effects on pain, function, and trunk muscle structures could be studied as the most critical factors affecting RLBP. The current study aimed to investigate the effects of external focus training on pain intensity, the thickness of TrA, internal oblique (IO), external oblique (EO), and lumbar multifidus (LM) muscles and the function of RLBP patients.

Materials and Methods

Study design

A single-blinded (assessor), parallel-group, randomized controlled trial (RCT) was conducted between June and November 2020. The study was registered on 2 Jun 2020 under the registration number (IRCT20200418047120N1). The Ethics Committee also approved this research of the authors' affiliated institutions on 15 Mar 2020 under the ethical number of (IR.IUMS.REC.1398.1368).

Sample size

Advanced statistical software, Stata version 14, was used to determine the sample size using the sampsi command. The method of determining the sample size for this study was a priori, based on the minimal clinically important difference (MCID) of pain, as the primary outcome. Data on the pain intensity variable was extracted from a study conducted by Halliday et al. [16] In that study, pain intensity after intervention in the control group (motor control training) was reported based on the visual analysis scale. Standard deviation (SD) was set at 2.3, power at 85%, and type I error was fixed at 5%. According to the calculation, the determined sample size for each group was 15 individuals. However, considering the 20% attrition rate, 19 participants were admitted to each group.

Participants

Inclusion criteria were: 1) people who had experienced RLBP (experiencing non-specific LBP at least twice in the past year that required medical attention or limited the patient's function,17 2) pain intensity between 30 and 60 at rest on 0 to 100 point numeric pain rating scale (NPRS) where 0 represents no pain and 100 is the worst imaginable pain, 3) age between 18 to 50 years old, 4) the participant's ability to perform therapeutic exercises, 5) sensory and motor health of upper and lower extremities. Exclusion criteria were: 1) deformity of extremities or spine, 2) any diseases that may disrupt exercise therapy (e.g., cardiac, respiratory, rheumatic), 3) any injury to the extremities or spine during exercise therapy, 4) absence of more than three sessions in treatment sessions, 5) pregnancy.

Randomization

The randomization process was performed using the 4-letter blocks made of letters A and B. Group A included external focus training with motor control training, and group B included motor control training alone. Considering that 38 people had to participate in the study and the blocks were 4-letter, ten random numbers were prepared, which determined the placement order of 4-letter blocks. Then, the randomization list with letters A and B was placed inside the numbered sealed opaque envelopes, and one envelope was assigned to each patient for a referral.

Outcome measures

In addition to NPRS, which was used to assess pain intensity as the primary outcome, three other functional indexes were used in this study: 1) Tampa kinesiophobia scale (TKS), which includes 17 items, and the score of each one is 1-4, the general score is 17-68 that more score shows more kinesiophobia, 2) Fear-avoidance beliefs questionnaire (FABQ), consists of 16 items and score of each item is 0-6. The first five items are classified as physics-related subscale, the last 11 items are classified as work-related subscale, and 3), Oswestry disability index (ODI) includes ten items that score of each one is 0-5, which presents the disability as a percentage.

The thickness of TrA, IO, EO, and LM muscles on both sides was measured using a sonography machine: SonoAce r7 with convex transducer (C2-8 prob, center frequency: 4.9 MHZ, 128 elements, 51 mmR, B-mode). Before using the sonography within and between sessions, intra-rater reliability was examined to measure and confirm the thickness of the mentioned muscles. Three images were taken in each condition (rest and contraction), and their average thickness was calculated and recorded. All assessment steps were performed by the first author, unaware of the grouping and patients' intervention type.

Transverse abdominis, internal oblique, and external oblique

The participants were instructed to lie supine and place their hands on the chest. A pillow was placed under the knees to flex hip and knee joints and support them [Figure 1a]. The transducer was placed transversely on the midaxillary line between the lower edge of the ribcage and the superior border of the iliac crest [Figure 1b].[18] Images were taken at the end of normal exhalation at the rest condition and measured from the thickest region of the muscles' belly to ensure the same condition in all participants [Figure 1c]. Muscle thickness was also measured in the abdominal draw-in maneuver (ADIM). To perform the ADIM, participants were instructed to take a relaxed breath in and out, hold the breath out, then draw in the lower abdomen without moving the spine and contract abdominal muscles by pulling the navel up and in toward the spine.[19]

Lumbar multifidus

Participants were positioned in a prone position. They were instructed to place their hands symmetrically next to the trunk [Figure 2a]. The examiners found the L5/S1 zygapophyseal joints by palpation and ultrasound image. Then, placed the transducer on them longitudinally and

Figure 1. Sonography imaging of transverse abdominis (TrA), Internal oblique (IO) and External oblique (EO) muscles

A: Position of the patient

B: Position of the transducer

C: A sample of sonography image (1: EO, 2: IO, 3: TrA, 4: Fascial layers)

recorded parasagittal images [Figure 2b]. According to the evidence, in the parasagittal plane, the zygapophyseal joints and overlying LM muscle bulk at 2 to 3 vertebral levels could be visualized and is suitable for measuring the LM muscle thickness.[20] After taking images at rest, the participants were instructed to flex the elbows and abduct the shoulders at approximately 90° and 120°, respectively. Then, they lifted their head, trunk, and upper extremities and held them with maximum effort for ultrasound imaging at muscle contraction condition.[21] A sample of the ultrasound image of LM is provided in [Figure 2c].

Intervention

First, the study steps were explained to the participants, and they were checked for inclusion and exclusion criteria. Patients who were eligible for the study completed a written informed consent. The procedure was conducted according to the declaration of Helsinki. Subsequently, the participants completed a basic profile form that included age, gender, stature, body mass, and the number of pain recurrences in the past year. After the first steps, participants were divided into two groups according to the random allocation list (A: intervention or B: control). After randomization, NPRS, TKS, FABQ, ODI, and thickness of TrA, IO, EO, and LM muscles were measured as a pre-intervention test.

One physiotherapist, unaware of the assessment steps, performed all interventions for both groups. Both groups received background intervention, including 20 min of conventional Transcutaneous Electrical Nerve Stimulation (frequency: 100 Hz, Pulse width: 40-75 µs, patient feeling: tingling) and about 15 min of common lumbar motor control training. In static and dynamic conditions, common motor control exercises were performed as the isolated and sub-maximal contraction in the target muscles. The exercises were progressive, and the therapist checked the patient's ability to contract the target muscles. If the patients were able to perform previous exercises, they would progress to the

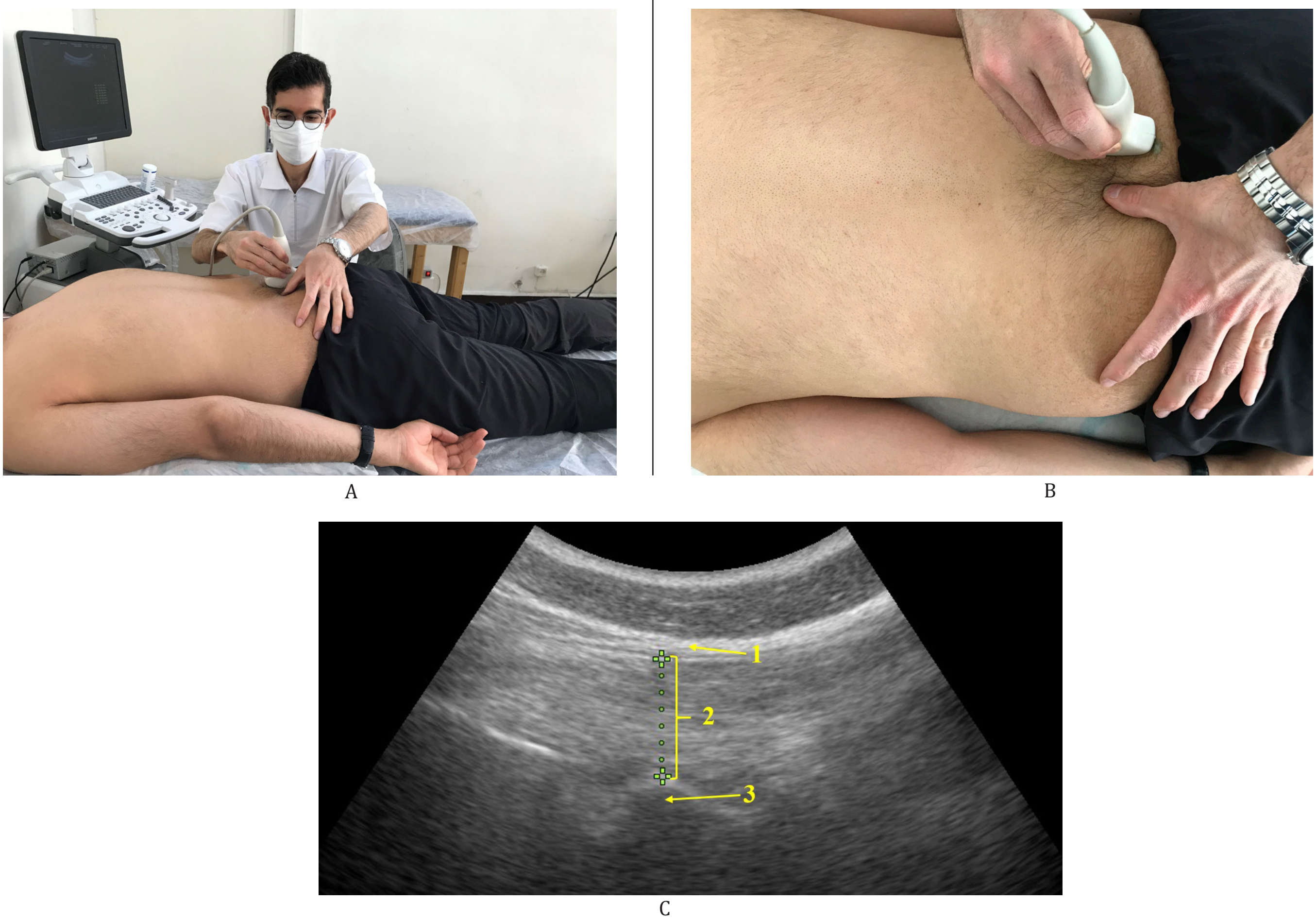

Figure 2. Sonography imaging of lumbar multifidus (LM) muscles.
A: Position of the patient
B: Position of the transducer
C: A sample of sonography image (1: Fascial layer, 2: LM, 3: L5/S1 zygapophyseal joint)

Figure 3. A sample of external focus training and external moving targets.

next step.

After doing background intervention, group (A) underwent external focus exercises. In this part, moving and unpredictable external targets (e.g., ball and dart) were provided as animations by software and displayed on a large screen using a video projector. The targets consisted of eight various animations, each moving at a specific speed. The patients were instructed to stand on a surface before the screen and focus on animation objects, then hit them with a light bar [Figure 3]. The distance between the patient and the screen was optimal to reach the targets and challenge the upper limbs and trunk. These exercises were progressive, and their progress was performed by two factors: reducing the distance between moving the external targets and increasing their speed (from 2 sec in the first sessions to 0.5 sec in the last session) and increasing their unpredictability. If the patients could do the slower exercises correctly, faster exercises were replaced. The whole external focus training lasted about 15 min. For all participants, three weekly sessions and 16 intervention sessions were held. Then, all the mentioned outcomes were examined again as the post-intervention test.

Statistical analysis

For all statistical analyzes, SPSS (version 21) was used. To examine the normal distribution of data, the Shapiro-Wilk test, mean and median proximity, and the degree of skewness and kurtosis of the data distribution were used. Due to the normal distribution of data and equality of variances, the parametric method, analysis of covariance (ANCOVA), was used to calculate the differences between the two groups. The data of the pre-intervention test were determined as the covariance in the ANCOVA test. A *P-value* less than 0.05 was considered statistically significant. Cohen's *d* effect size index was also used for each variable to compare the two interventions and determine their effect regardless of the sample size. The effect size is interpreted as: d (0.01) = very small, d (0.2) = small, d (0.5) = medium, d (0.8) = large, d (1.2) = very large, and d (2.0) = huge .14

Results

Different phases of the study are presented in the consort flowchart [Figure 4]. The data of 38 participants [17 males and 21 females, age: 37.63(8.33), body mass: 69.68(9.08) kg, stature: 168.42(6.73) cm] were included in the analysis. Participants' detailed demographic and descriptive characteristics before the intervention are presented in [Table 1].

Analytical statistics of pain, muscle thickness, TKS, FABQ, and ODI are available in [Table 2]. According to the ANCOVA test, external focus training with motor control training was significantly effective in pain reduction more than motor control training alone. The between-group mean difference in pain was significant (-10.53 (9.70), *P<0.001*). In addition, its effect size was very large (Cohen's *d*=-1.47). Furthermore, a significant mean difference was proved in the right and left TrA muscles (*P*=0.03, Cohen's *d*=0.44 and *P<0.001*, Cohen's *d*=1.05 for Rt and Lt TrA, respectively). The thickness of IO, EO, and LM muscles in the intervention group was not significantly different from the control group. Moreover, TKS, FABQ, and ODI analysis showed no significant difference in these indexes. However, the effect size for TKS was medium (Cohen's *d*=-0.53) and better than FABQ and ODI (Cohen's *d*=-0.26 and -0.19, respectively).

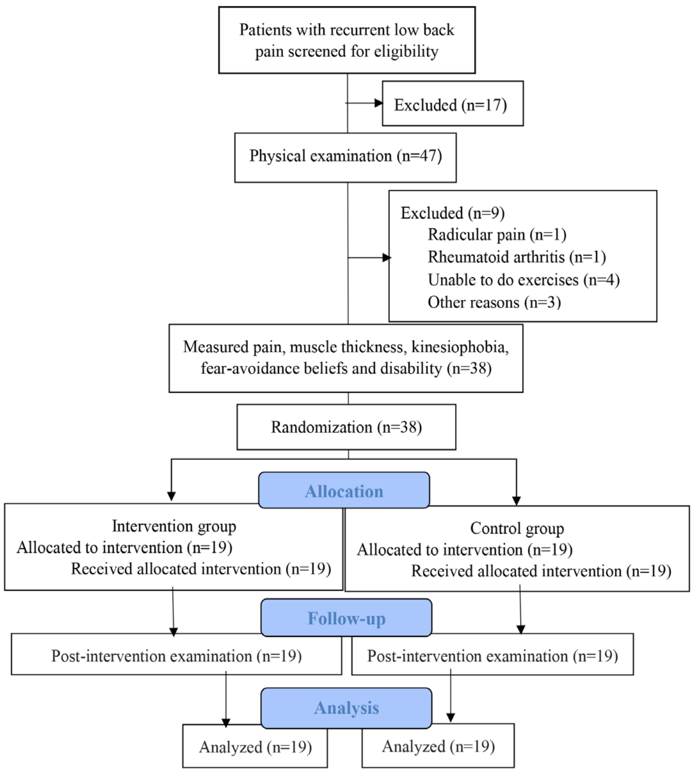

Figure 4. Flow chart of the different phases of the study.

Table 1. Descriptive statistics of participants before intervention

Characteristic		Intervention	Control
Gender[a]		M: 9 (47.4%) F: 10 (52.6%)	M: 8 (42.1%) F: 11 (57.9%)
Age		36.37 (8.24)	38.89 (8.46)
Body mass		68.26 (8.81)	71.10 (9.35)
Stature		168.21 (7.29)	168.63 (6.31)
Pain recurrence		3.37 (1.60)	3.79 (1.58)
NPRS[b]		55.79 (7.68)	55.26 (6.12)
TKS[c]		41.95 (8.55)	44.21 (6.50)
FABQ (P)[d]		17.21 (4.33)	18.42 (4.46)
FABQ (W)[e]		22.42 (8.39)	20.79 (7.91)
ODI[f]		28.00 (12.45)	31.68 (7.87)
Right TrA[g]	Rest	2.84 (0.78)	3.01 (0.92)
	ADMI[h]	4.55 (0.98)	4.68 (1.52)
Left TrA	Rest	2.93 (1.03)	2.67 (0.82)
	ADMI	4.94 (1.18)	4.60 (1.38)
Right IO[i]	Rest	5.95 (2.07)	5.56 (1.76)
	ADMI	6.91 (2.45)	6.74 (3.87)
Left IO	Rest	6.08 (1.66)	5.42 (1.89)
	ADMI	7.55 (2.30)	6.95 (2.76)
Right EO[j]	Rest	4.72 (1.69)	4.47 (1.55)
	ADMI	4.27 (1.43)	4.60 (1.61)
Left EO	Rest	4.72 (1.40)	4.96 (1.51)
	ADMI	4.85 (1.73)	4.99 (1.60)
Right LM[k]	Rest	25.57 (4.31)	26.47 (5.52)
	LE[l]	32.76 (3.99)	34.05 (4.86)
Left LM.	Rest	26.67 (4.05)	27.74 (5.24)
	LE	33.44 (4.30)	34.31 (5.17)

[a]: data are presented as mean ± mean difference (SD),
[b]: numerical pain rating scale, [c]: Tampa kinesiophobia scale,
[d]: fear-avoidance beliefs (physical subscale), [e]: fear-avoidance beliefs (work related subscale), [f]: oswestry disability index, [g]: transverse abdominis,
[h]: abdominal draw-in maneuver, i: internal oblique, [j]: external oblique,
[k]: lumbar multifidus, [l]: lumbar extension.

Discussion

The primary aim of this study was to investigate the effect of external focus training with motor control training compared to motor control training alone on pain. Secondary aims were the thickness of TrA, IO, EO, and LM muscles, kinesiophobia, fear-avoidance beliefs, and disability of patients with RLBP. Studies that have examined external focus on the lumbar region are minimal. Only some considered the immediate effects but did not use it as an intervention, making it difficult to compare the results.[14,22]

The results showed that the pain in the intervention group significantly reduced more than in the control group. Other studies that have used external focus for musculoskeletal disorders have confirmed its positive effects on reducing pain and improving function.[15] The relationship between trunk muscles background activity (especially during movements of upper limbs) and pain is one of the critical issues that has been investigated in RLBP patients.[23] Evidence suggests that the risk of LBP increased by 3% for every millisecond of abdominal muscle delay during movements of the upper limbs.[24] Previous studies have shown that in RLBP patients, movements of different spinal column parts are performed more independently and uncoordinated than in healthy people.[25] External focus training is not isolated at a certain level of the musculoskeletal system and could improve coordination between different parts of the spine; however, some studies contradicted this idea. In 2009, Hall et al. provided non-isolated motor control training for patients with RLBP and found that a single session of non-isolated training of the trunk muscles could not improve the motor control of the deep abdominal muscles of RLBP patients.[26]

The between-group mean difference in muscle thickness was significant in the contraction condition (ADIM) of TrA muscle. No significant between-group mean difference was observed in other muscles. Considering the large variety of effect sizes, it shows that one model of external focus training cannot be expected to have the same effect on all trunk muscles. A similar conclusion could be interpreted from a study by Calatayud et al. In the mentioned study, the difference between the recruitment of different abdominal muscles during internal and external focus was investigated during plank exercise. However, it was observed that only the activity of the rectus abdominis muscle changed due to the type of focus.[14]

The external focus training in this study required free movements of the upper extremities, which could challenge the TrA muscle and may cause more recruitment. Feedforward activity of TrA, before the movements of the upper extremities, could prepare the spine for perturbations.[27] It could be trained during external focus training.

The activity of TrA is also associated with postural demands in a standing position.28 Therefore, postural challenges during external focus training could also recruit TrA more and could be another reason for the increase in its thickness. Some other studies have suggested other factors as a result of external focus training (e.g., the effect of the therapist's instructions on the external focus). In a study by bourdon et al., the dynamic stability of the lumbar spine flexion during external and internal focus was investigated, and it was observed that the type of therapist instructions also plays an important role.[22]

Analysis of TKS, FABQ, and ODI showed that the mean difference was not significant and effect sizes were moderate. Differences in the effect size of TKS, FABQ,

Table 2. Analytical statistics of participants after intervention

Characteristic		Mean (SD[a])		Mean difference (SD)	P-value	Effect Size (CI[b])
		Control	Intervention			
NPRS[c]		6.31 (5.97)	16.84 (8.20)	-10.53 (9.70)	**<0.001***	-1.47 (-2.48, -0.45)
TKS[d]		35.47 (7.38)	39.42 (7.53)	-3.95 (9.51)	0.20	-0.53 (-1.44, 0.39)
FABQ (P)[e]		13.31 (5.71)	14.79 (5.62)	-1.47 (8.29)	0.59	-0.26 (-1.16, 0.64)
FABQ (W)[f]		17.05 (6.11)	18.74 (6.80)	-1.68 (6.02)	0.24	-0.26 (-1.16, 0.64)
ODI[g]		14.21(11.31)	16.10 (8.47)	-1.89 (13.19)	0.77	-0.19 (-1.09, 0.71)
Right TrA[h]	Rest	3.56 (0.76)	3.33 (0.96)	0.23 (0.97)	0.13	0.26 (-0.64, 1.17)
	ADMI[i]	5.15 (0.84)	4.67 (1.33)	0.49 (1.71)	**0.03***	0.44 (-0.47, 1.35)
Left TrA	Rest	3.84 (0.94)	3.25 (0.88)	0.59 (1.01)	0.05	0.65 (-0.27, 1.57)
	ADMI	5.80 (1.03)	4.66 (1.13)	1.14 (1.67)	**<0.001***	1.05 (0.09, 2.01)
Right IO[j]	Rest	6.77 (2.48)	5.85 (2.30)	0.91 (3.67)	0.25	0.38 (-0.53, 1.29)
	ADMI	7.80 (2.62)	6.92 (3.84)	0.88 (5.34)	0.05	0.27 (-0.64, 1.17)
Left IO	Rest	6.98 (1.50)	5.93 (2.11)	1.04 (2.75)	0.18	0.57 (-0.35, 1.48)
	ADMI	8.26 (1.82)	7.03 (2.68)	1.22 (3.42)	0.11	0.53 (-0.38, 1.45)
Right EO[k]	Rest	5.04 (1.29)	4.83 (1.85)	0.21(2.21)	0.97	0.13 (-0.77, 1.03)
	ADMI	4.81 (1.24)	4.97 (1.60)	-0.16 (2.06)	0.71	-0.11 (-1.01, 0.79)
Left EO	Rest	5.46 (2.02)	4.77 (1.38)	0.68 (2.18)	0.09	0.39 (-0.51, 1.30)
	ADMI	5.31 (2.10)	4.74 (1.38)	0.57 (2.20)	0.05	0.32 (-0.58, 1.22)
Right LM[l]	Rest	28.02 (3.68)	28.34 (6.04)	-0.32 (6.40)	0.60	-0.06 (-0.96, 0.83)
	LE[m]	35.36 (3.64)	35.32 (6.31)	0.03 (6.67)	0.45	0.01 (-0.89, 0.91)
Left LM	Rest	28.92 (5.74)	28.29 (5.80)	0.64 (8.82)	0.22	0.11 (-0.79, 1.01)
	LE	35.41 (3.72)	35.98 (6.26)	-0.57 (7.62)	0.83	-0.11 (-1.01, 0.79)

[*]: significant mean difference, [a]: standard deviation, [b]: confidence interval, [c]: numerical pain rating scale, [d]: Tampa kinesiophobia scale, [e]: fear-avoidance beliefs (physical subscale), [f]: fear-avoidance beliefs (work related subscale), [g]: oswestry disability index, [h]: transvers abdominis, [i]: abdominal draw-in maneuver, [j]: internal oblique, [k]: external oblique,
[l]: lumbar multifidus, [m]: lumbar extension.

and ODI could be found in their items. The TKS does not ask about the physical condition of the person. It only examines the patient's view about pain and factors that may affect it. Evidence proved that the patient's perception of pain could play an essential role in physical treatment.29The sport and functional nature of external focus training in the present study may help the patients have more confidence and a more positive view of the body's physical capacity.

In FABQ and ODI, unlike TKS, in addition to spiritual factors, the physical dimensions of the patients were examined. The patients had physical problems that they had experienced repeatedly for at least one year. More intensive or prolonged intervention to improve and achieve greater effect size seemed to be required regarding some parts, such as item 9 of ODI (social life).

Study limitations

The first limitation of the study was the available technology. The used set-up for external focus training was designed one-way, meaning that the patients could not immediately see the result of their action and get feedback or effect on the practice process. If there was a system that could interact more with the patients and have two-way communication, the protocol could be better. The second limitation was the patients' pain which could interrupt the sonography imaging process. By monitoring the image and taking it at the patient's stable condition, training the patient, three repeats of the imaging, and taking the average, this problem in the assessment was minimized.

Suggestions

The first suggestion is to use a two-way set-up for external focus training. If a system that could receive the patient's movement information at the same time as the exercise and present external targets according to the patient's performance is used, the patient could receive appropriate feedback during the exercise. Another idea is using electromyography to examine the course of changes in the underlying and postural activity of the deep trunk muscles, especially the transverse abdominal muscle, during external focus exercises.

Based on the obtained results, external focus training with motor control training could significantly reduce RLBP patients' pain. This training could also significantly increase the thickness of the TrA muscle as one of the important deep trunk muscles. However, it did not show a significant group mean differences in IO, EO, and LM muscle thickness. Furthermore, the effect of external focus training with motor control training in comparison with motor control training on kinesiophobia was moderate; however, it seemed that this intervention was not enough to improve kinesiophobia, fear-avoidance beliefs, and disability.

Declarations of interest: None.

Hamid Zamani PhD PT[1]
Mahdi Dadgoo PhD PT[1]
Mohammad Akbari PhD PT[1]
Javad Sarrafzadeh PhD PT[1]
Mohammadreza Pourahmadi PhD PT[1]
1 Rehabilitation Research Center, Department of Physiotherapy, School of Rehabilitation Sciences, Iran University of Medical Sciences, Tehran, Iran

References

1. Hoy D, March L, Brooks P, et al. The global burden of low back pain: estimates from the Global Burden of Disease 2010 study. Ann Rheum Dis 2014;73(6):968-74. doi: 10.1136/annrheumdis-2013-204428.
2. Balague F, Mannion AF, Pellise F, Cedraschi C. Non-specific low back pain. Lancet 2012;379(9814):482-91. doi: 10.1016/S0140-6736(11)60610-7.
3. Hoy DG, Smith E, Cross M, et al. Reflecting on the global burden of musculoskeletal conditions: lessons learnt from the global burden of disease 2010 study and the next steps forward. Ann Rheum Dis 2015;74(1):4-7. doi: 10.1136/annrheumdis-2014-205393.
4. Tulder MV, Koes B , eds. Evidence-Based Medicine for Low Back Pain. in:Spinal Imaging. MR: Springer, Berlin, Heidelberg ;2007.
5. Da Silva T, Mills K, Brown BT, Herbert RD, Maher CG, Hancock MJ. Risk of Recurrence of Low Back Pain: A Systematic Review. J Orthop Sports Phys Ther 2017;47(5):305-13. doi: 10.2519/jospt.2017.7415.
6. Fattahi AS, Maddah G, Motamedolshariati M, Ghiasi–Moghadam T. Chronic low back pain due to retroperitoneal cystic lymphangioma. Arch Bone Jt Surg 2014;2(1):72.
7. Soderberg GL, Barr JO. Muscular function in chronic low-back dysfunction. Spine 1983;8(1):79-85. doi: 10.1097/00007632-198301000-00014.
8. Seraj MS, Sarrafzadeh J, Maroufi N, Takamjani IE, Ahmadi A, Negahban H. The ratio of lumbar to hip motion during the trunk flexion in patients with mechanical chronic low back pain according to o'sullivan classification system: a cross-sectional study. Arch Bone Jt Surg 2018;6(6):560.
9. Bystrom MG, Rasmussen-Barr E, Grooten WJ. Motor control exercises reduces pain and disability in chronic and recurrent low back pain: a meta-analysis. Spine 2013;38(6):E350-8. doi: 10.1097/BRS.0b013e31828435fb.
10. Delitto A, George SZ, Van Dillen L, et al. Low back pain. J Orthop Sports Phys Ther 2012;42(4):A1-57. doi: 10.2519/jospt.2012.42.4.A1.
11. Hides JA, Jull GA, Richardson CA. Long-term effects of specific stabilizing exercises for first-episode low back pain. Spine 2001;26(11):E243-8. doi: 10.1097/00007632-200106010-00004.
12. Wulf G, Prinz W. Directing attention to movement effects enhances learning: a review. Psychon Bull Rev 2001;8(4):648-60. doi: 10.3758/bf03196201.
13. Wulf G, McNevin N, Shea CH. The automaticity of complex motor skill learning as a function of attentional focus. Q J Exp Psychol A 2001;54(4):1143-54. doi: 10.1080/713756012.
14. Calatayud J, Casaña J, Martín F, Jakobsen MD, Andersen LL, Colado JC. Electromyographic Effect of Using Different Attentional Foci During the Front Plank Exercise. Am J Phys Med Rehabil 2019;98(1):26-9. doi: 10.1097/PHM.0000000000001008.
15. Hunt C, Paez A, Folmar E. The impact of attentional focus on the treatment of musculoskeletal and movement disorders. Int J Sports Phys Ther 2017;12(6):901-7.
16. Halliday MH, Pappas E, Hancock MJ, et al. A Randomized Controlled Trial Comparing the McKenzie Method to Motor Control Exercises in People With Chronic Low Back Pain and a Directional Preference. J Orthop Sports Phys Ther 2016;46(7):514-22. doi: 10.2519/jospt.2016.6379.
17. Stanton TR, Latimer J, Maher CG, Hancock M. Definitions of recurrence of an episode of low back pain: a systematic review. Spine 2009;34(9):E316-22. doi: 10.1097/BRS.0b013e318198d073.
18. Critchley DJ, Coutts FJ. Abdominal muscle function in chronic low back pain patients: measurement with real-time ultrasound scanning. Physiotherapy

2002;88(6):322-32. https://doi.org/10.1016/S0031-9406(05)60745-6

19. Koppenhaver SL, Hebert JJ, Fritz JM, Parent EC, Teyhen DS, Magel JS. Reliability of rehabilitative ultrasound imaging of the transversus abdominis and lumbar multifidus muscles. Arch Phys Med Rehabil 2009;90(1):87-94. doi: 10.1016/j.apmr.2008.06.022.
20. Hides J, Richardson C, Jull G, Davies S. Ultrasound imaging in rehabilitation. Aust J Physiother 1995;41(3):187-93. doi: 10.1016/S0004-9514(14)60429-3.
21. Kiesel KB, Uhl TL, Underwood FB, Rodd DW, Nitz AJ. Measurement of lumbar multifidus muscle contraction with rehabilitative ultrasound imaging. Man Ther 2007;12(2):161-6. doi: 10.1016/j.math 2006.06.011.
22. Bourdon E, Ramos Jr W, Mavor MP, Beaudette SM, Graham RB. The effect of attentional focus on local dynamic stability during a repetitive spine flexion task. J Biomech 2018;80:196-9. doi: 10.1016/j.jbiomech.2018.09.015.
23. Hodges PW, Richardson CA. Altered trunk muscle recruitment in people with low back pain with upper limb movement at different speeds. Arch Phys Med Rehabil 1999;80(9):1005-12. doi: 10.1016/s0003-9993(99)90052-7.
24. Cholewicki J, Silfies SP, Shah RA, et al. Delayed trunk muscle reflex responses increase the risk of low back injuries. Spine 2005;30(23):2614-20. doi: 10.1097/01.brs.0000188273.27463.bc.
25. Rowley KM, Smith JA, Kulig K. Reduced trunk coupling in persons with recurrent low back pain is associated with greater deep-to-superficial trunk muscle activation ratios during the balance-dexterity task. J Orthop Sports Phys Ther 2019;49(12):887-98. doi: 10.2519/jospt.2019.8756. doi: 10.2519/jospt.2019.8756.
26. Hall L, Tsao H, MacDonald D, Coppieters M, Hodges PW. Immediate effects of co-contraction training on motor control of the trunk muscles in people with recurrent low back pain. J Electromyogr Kinesiol 2009;19(5):763-73. doi: 10.1016/j.jelekin.2007.09.008.
27. Hodges PW, Richardson CA. Inefficient muscular stabilization of the lumbar spine associated with low back pain. A motor control evaluation of transversus abdominis. Spine 1996;21(22):2640-50. doi: 10.1097/00007632-199611150-00014.
28. Crommert ME, Ekblom MM, Thorstensson A. Activation of transversus abdominis varies with postural demand in standing. Gait Posture 2011;33(3):473-7. doi: 10.1016/j.gaitpost.2010.12.028.
29. Foster NE, Bishop A, Thomas E, Main C, Horne R, Weinman J, et al. Illness perceptions of low back pain patients in primary care: what are they, do they change and are they associated with outcome? Pain 2008;136(1-2):177-87. doi: 10.1016/j.pain.2007.12.007.