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Increasing Activity and Co-contraction of Local Muscles in the Core Region and Lumbopelvic Motor Control through Immediate Respiratory Muscle Training: A Double-Blind Randomized Controlled Trial

Leila Ahmadnezhad[1], Ali Yalfani[1*], Behnam Gholami-Borujeni[1]

1. Department of Sport Injury and Corrective Exercise, Bu-Ali University, Hamadan, Iran

ABSTRACT

Background: Core muscles play an important role during sports activities and these muscles control trunk stability via appropriate contraction. This study aimed to investigate the effect of immediate respiratory muscle sprint-interval training (RMSIT) on the activity of the selected trunk muscles and lumbopelvic motor control in athletes with chronic low back pain (CLBP).

Methods: A double-blind randomized controlled trial design was used for this study. The study population, 48 young athletes aged 18-25 years with CLBP, was randomly divided into training (n = 24) and control groups (n = 24). The study procedure was explained to the subjects. RMSIT was performed by the training group using a spirometer. The training program included six sets of 30-second breathing exercises. Surface electromyography of the selected local (transverse abdominis, multifidus) and global (erector spinae, rectus abdominis) muscles of the trunk and lumbopelvic motor control and patients' perceived low back pain in pre- and post-tests were recorded in both groups.

Results: The results showed that the activity of the transverse abdominis and co-contraction of local muscles significantly increased ($P \leq 0.05$) in the training group during static and dynamic overhead squat and single-leg squat. In addition, lumbopelvic stability in the right and left side significantly improved in the training group.

Conclusion: RMSIT can improve local muscle activity and co-contraction of local muscles activity in athletes with CLBP. Moreover, these training can improve lumbopelvic stability.

Keywords: Respiratory training, Electromyography, Low back pain, Overhead squat, Single-leg squat, Lumbopelvic stability

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***Correspondence:** Ali Yalfani; Email: Ali_yalfani@yahoo.com

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Introduction

Low back pain is the fifth most common reason for physician visits, which affects nearly 60-80% of people throughout their lifetime (1). Low back pain that has been present for longer than three months is considered chronic, although there is still no consensus about the definition of chronic low back pain (CLBP) (2).

Muscle is a potential source of low back pain (3). Researchers have expressed that weakness of the muscles to protect passive structures in excessive loading may cause pain especially back pain (4).

CLBP affects the lumbopelvic stability and motor control of the trunk muscles. Maintenance of lumbopelvic position during limb movements is known as lumbopelvic motor control (3). Muscles that maintain the lumbopelvic and lumbar spine stability are divided into two local and global groups (5). The transverse abdominal and lumbar multifidus are examples of local muscles, which are also among the trunk core ones (6). In this respect, co-contraction of transverse abdominis and lumbar multifidus muscles is significantly important for creating stability in the lumbar spine (7). In the context of the transversus abdominis muscle, studies have demonstrated delayed anticipatory activation and reduced thickness in those with low back pain (1,8).

Pinto *et al.* reported that the thickness of the local stabilizer muscles decreased in individuals with CLBP, resulting in reduced activities of these muscles as well as the stability of the lumbar spine (9). In this situation, the activities of the global muscles increase in order to compensate diminished activities of local muscles and to maintain segmental stability, which all lead to increased pressure on the lumbar spine and recurrence of CLBP in a long-term period (9). The excessive activity of the global muscles can be the reason for changing the respiratory pattern in such patients (10). While this condition may also exist in individuals with no pain, a disturbance in the local muscles might be associated with the emergence of CLBP over time (11). Weakness and atrophy will occur in case of intensified pain in individuals with CLBP (12), which leads to the stiffness of the ligament and joints, and subsequently, reduces activity of core muscles (13). It is essential to maintain a proper pattern of muscle activity as well as muscle strength (14). The intra-abdominal pressure caused by the connection between the trunk and the respiratory stabilizer muscles, similarly affects lumbar stability (7). The use of respiratory exercises can relieve muscle tension in individuals suffering from CLBP (15). In addition, increased intra-abdominal pressure due to respiratory exercises is possibly associated with activation of the pelvic floor muscle, which activates local stabilizer muscles by abdominal muscle contraction during breathing (15).

Respiratory muscle training has been recognized as one of the exercises used in sports medicine, rehabilitation, and medical care to increase the strength and endurance of respiratory muscles and functional capacity and to improve quality of life in individuals (16,17). Given the fact that athletes are currently dealing with CLBP, a point prevalence ranging from 10% to 67% has been reported in them (18). The range of motions and velocity in patients with CLBP causes a reduction in the compensation for respiratory distress, the enhancement of postural sway, and a greater perturbation compared with people without this condition (19). Regarding the importance of research in this domain, Based on theoretical long-term inspiratory exercises are likely to affect core muscle activity and improve pulmonary parameters, but to the best of our knowledge, there is no study on the effect of RMSIT. As CLBP is a common problem in athletes, clinicians have to be able to identify the most effective available treatments for this group. The study hypothesis is that RMSIT is effective in this population. This double-blind randomized controlled trial investigated the immediate effect of RMSIT on the selected local and global trunk muscles, lumbopelvic stability and patient's perceived low back pain in athletics with non-specific CLBP.

Materials and Methods

Study design

In this study, a double-blind randomized controlled trial design was used. Participants and investigators were blinded. All tests and procedures were performed by the same investigator. The study protocol was approved and registered by the local Ethics Committee (Ethical Code: UMSHA.REC.1396.933) following standards and guidelines of the Declaration of Helsinki.

Participants

The participants included 48 (female=24 and male=24) weightlifting and powerlifting athletes who suffered from CLBP. The age range of the participants was 18-25 years. The demographic characteristics were investigated at the baseline which are shown in Table 1. Inclusion criteria include male and female athletes aged 18 to 25 years with a history of low-back pain and symptom duration more than 3 months who continuously and regularly performing weightlifting and powerlifting exercises three sessions per week and at least 75 minutes per session over the last three years, duration of CLBP symptoms between 3 months and above, and pain scores between 3 to 6 out of 10 on the Visual Analogue pain scale (19). Exclusion criteria include low-back pain attributable to any pathology, history of trauma, or any neurological condition, existence of spinal deformity and orthopedic or neurological diseases and injury to the spine and the chest, history of smoking, history of cardiovascular and pulmonary diseases, subjects who had undergone spinal surgery, and also, infections of the spine, and already participating in other trial for low-back pain and pregnant women.

Table 1. Subjects' characteristics

Variable	**Control Group (n=24)**	**Training Group (n=24)**	**P-value**
	Mean ± SD	**Mean ± SD**	
Age (year)	22.33±1.41	21.43±2.15	0.680
Height (cm)	166.97±8.83	168.26±10.37	0.281
Body mass (kg)	60.13±9.43	63.23±11.38	0.112
Body mass index (kg.m^{-2})	21.60±2.62	22.17±2.88	0.142
VC-IN	4.02±0.11	3.91±0.15	0.096
FVC	4.22±0.29	4.18±0.20	0.591
FEV1	4.07±0.09	4.04±0.09	0.634
FEV/VC	76.95±2.55	76.68±2.14	0.470
LAI (deg)	29.22±5.40	31.12±4.34	0.107

VC-IN: Vital capacity inspiratory.
FVC: Forced vital capacity.
FEV1: Forced expiratory volume in 1 sec.
LAI: Lumbar Arch Index.

Power calculation was performed using G*Power with 95% power, 0.80 effect size, and $\alpha = 0.05$ (20).

Before initiating the study program, the subjects were randomly assigned by an independent researcher into two training (male = 11, female = 13) and control (male = 11, female = 13) groups using Random Allocation Software (21). The schematic diagram of the subjects selection method is presented in Figure 1. Signed informed consent was obtained from all participants who were willing to participate in the study.

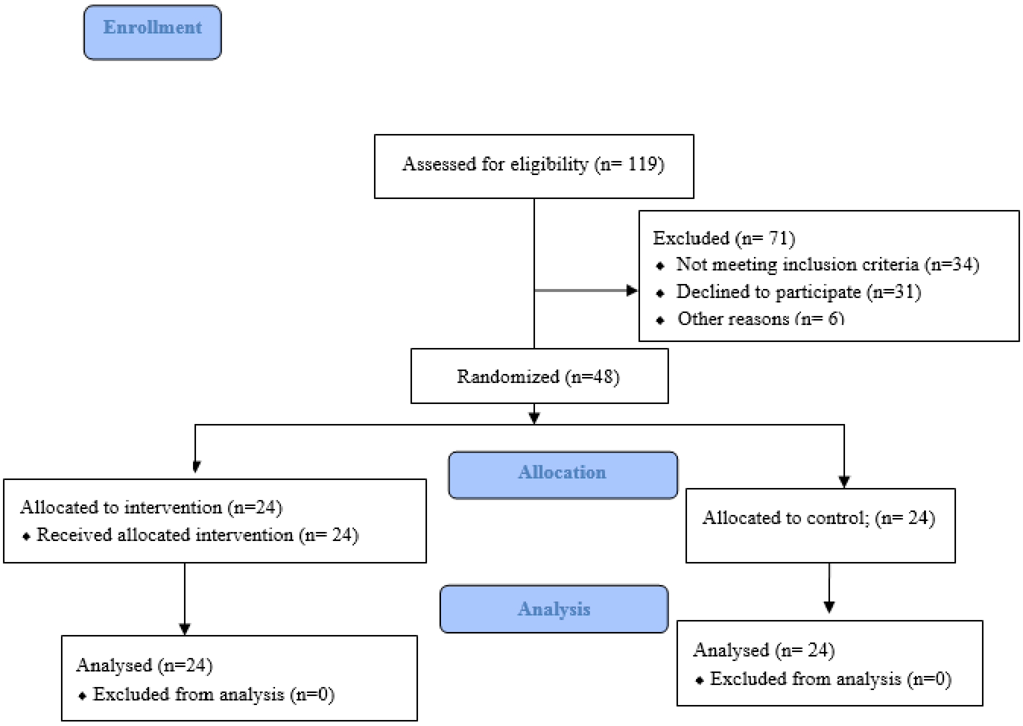

Figure1. Clinical trial setup

Procedure and task

Before starting the research process, the investigator explained some instructions to the subjects, such as they should not do intense exercise for two days before the test or not consume caffeine before the test.

The day before the RMSIT, a JAEGER Spirometer (Oxycon, Delta, Germany) was used to measure the respiratory capacity of the subjects. The relevant information in this regard is presented in Table 1.

On the test day and before performing the respiratory exercises, the examiner ordered the both groups to warm up for 6 minutes by an ergometer bicycle (894 E Monark Ergomedic Peak Bike; Monark, Varberg, Sweden) at 40% of the maximum heart rate for 3 minutes. They were also directed to perform 3 minutes of full-body stretching.

In this study, the electrical activity of the muscles was recorded during static and dynamic overhead squats and single-leg squats (22).

These tests are the sample of key assesment for functional performance tests, which are used in rehabilitation and orthopedic and athletic assessment screening tool to evaluate the movement system (23). These tests have reliability in detecting abnormal kinematics in lower extremity and trunk (24). The duration of the static overhead and single-leg squats was 30 seconds. The dynamic squats included descending and ascending phases. The duration of the dynamic squats was 4 seconds. The movement speed was controlled using a metronome with 30 beats per min (cycle period = 4 s, descending phase = 2 s, and ascending phase = 2 s). To perform the static and dynamic overhead squats, the subjects stood with their feet shoulder-width apart, at a 10° foot placement angle and the knee angle determined at 90°. In the static and dynamic single-leg squats, the subjects stood on their dominant foot with their hands on their hips, feet pointing straight ahead, and the knee angle determined at 110°. A flexible electrogoniometer (SG150; Biometrics Ltd, Newport, United Kingdom) was used to capture the knee joint angle when performing the movement and determining when the knee reaches the desired angle; this device was attached to the lateral aspect of their knee. The participants descended from a standing position into the overhead and single-leg squats, and no external load was used for these tests. All the participants performed the static and dynamic overhead and single-leg squat tests in the pre-and post-test (25). The participants performed a complete squat, and data were recorded accordingly. Three successful trials were run, in both, the static and dynamic overhead and single-leg squats were included (26). A trial that was unmistakably positioned in some parts of the body as well as the angle of the knee was considered as a successful trial. A 2-minute rest period was adopted between the trials.

Surface electromyography recording

For recording the trunk muscle activity, the skin of the muscle location was shaved. Then, cleaned via alcohol following Surface EMG for Non-Invasive Assessment of Muscles (SENIAM) recommendations to place the electrode after recognizing the anatomical landmarks for each of the four selected muscles: Erector Spinae, Multifidus, Transverse Abdominis, and Rectus Abdominis.

Surface electrode with Ag/AgCl material (ECG Electrodes; Skintact, Innsbruck, Austria) was positioned at the skin location immediately above the muscle tissue in a way that there was a 2-cm distance between the centers of the two electrodes (27). In addition, the reference electrode was placed on the athletes' acromion. The surface EMG device (Biomonitor ME6000 T16, Mega Electronics Ltd., Kuopio, Finland) synced with an electrogoniometer was applied to record the electrical activity of the muscles in both training and control groups. Sampling frequency was determined at 1000 Hz. A band-pass filter (10–500 Hz) was used to eliminate the effects of other factors influencing the signal. The EMG data were recorded using MegaWin and analyzed by MATLAB (MATLAB, MathWorks, Natick, Massachusetts, USA) software. A maximum voluntary isometric contraction (MVIC) of each muscle was recorded after the post-test and used to normalize the EMG signals. The MVIC was measured against manual resistance for 5 seconds, and after excluding one second from the first and last parts, the 3 seconds situated in the middle of the signal were used as the MVIC (28). The MVIC was obtained from the average of the three trials for each muscle (28).

In the static squats, the signal recording began when the individual was fixed at the desired angle, and with the completion of the period, the data recording was completed. In the dynamic squats, with the participant's movement, signal recording was started; by changing the squat phases when reaching the desired angle and providing verbal feedback, the participant changed the squat phase.

Lumbopelvic stability

Lumbopelvic motor control function was assessed using the lumbopelvic stability test (29,3). To measure lumbopelvic motor control function, the participants flexed their hip and knee to 90° in the supine position. Ipsilateral hip and knee extensions were performed to maintain abdominal pressure without the leg or foot touching a supporting surface. Abdominal pressure was measured with a pressure biofeedback unit (PBU) (Stabilizer; Chattanooga Group Inc., Hixson, TN, USA). The PBU was set to 40 mmHg and placed below the lordotic curve of the spine between S1 and L1, with the hip and knee in 90° flexion. Then, the pressure of the biofeedback device was increased by 10 mmHg, while the abdominal drawing-in maneuver was performed by the participants. The range of motion of hip extension was defined as the lumbopelvic stability function and measured on both sides when the pressure decreased to <50 mmHg during hip extension, this test has a high intra-rater reliability (3).

The flexible electrogoniometer was used to measure the range of motion of hip extension while the lumbopelvic was stable. Three successful trials were run on each side.

Pain index

At the pre- and post-test, patient's perceived low back pain was assessed using a 10-cm Visual Analog Scale (30).

Intervention

After recording the pre-test data, the training group patients were asked to go to the training room. The training protocol was performed under the guidance of the same therapist. The training group participants were given a Respiratory Muscle Sprint-Interval Training (RMSIT) protocol in a sitting position. The RMSIT were performed with the POWERbreathe (POWERbreatheKH1, HaB International Ltd, Southam, UK) handheld device by the training group. The POWERbreathe device was applied for testing and checking the intensity of training. The RMSIT was fulfilled in 6 sets of 30-second breathing exercises (with 2 minutes of rest between the sets) with constant tidal volume in each set, training intensity started with 60% of maximum inspiratory pressure ($P_{i,\,max}$) using the manual set-up option. The overall training intensity was increased gradually. Training pressure was increased by 5% per set to a maximum of 85% $P_{i,\,max}$ (26). The control group also had no activity for 15 minutes, after pre-test (similar time to the protocol performed by the training group) (26). Subsequent to the RMSIT exercises, a post-test was performed in both groups similar to that in the pre-test stage.

Statistical analysis

The data were analyzed using SPSS version 20 (SPSS Inc., Chicago, Illinois, USA). The results of the Shapiro-Wilk test in each group showed that data distribution in the study variables in the groups was normal (P > 0.05). The Levene's test results for the assumption of equality of error variances also indicated no significant difference between the variance of variables mentioned in both groups (P > 0.05). The results of MANOVA in the pre-test showed that there were no significant differences between the control and training groups in subjects' characteristics (anthropometric variables and respiratory indices) (Table 1), EMG in the overhead squat (Table 2), EMG in the single-leg squat (Table 3), lumbopelvic motor control, pain, paired sample t-tests, and a two-way repeated-measures ANOVA with Bonferroni's post-hoc test were used to analyze the effect of immediate RMSIT on the dependent variables. The partial eta-squared effect size was assessed for the two-way analysis of variance (group × time interaction). Cohen's d was used to indicate the effect sizes in the event of statistically significant differences. The significance level was considered at α = 0.05.

Table 2. Two-way repeated measures ANOVA test in the overhead squat test (mean ± standard deviation)
Static Overhead Squat

	Control Group (%MIVC)		**Training Group (%MIVC)**		**Two-way ANOVA**	***d***
Muscles	**Pre-test**	**Post-test**	**Pre-test**	**Post-test**		
Erector spinae	32.24±8.63	34.45±10.16	30.27±9.16	28.38±11.94	0.431	0.027
Multifidus	20.76±7.21	20.96±8.50	18.32±5.50	20.96±8.50	0.252	0.054
Rectus abdominis	18.03±5.38	17.12±6.96	19.80±9.13	17.09±7.50	0.259	0.055
Transverse abdominis	9.47±5.51	9.91±6.64	8.55±3.38	13.14±6.14[a]	0.017*	0.225
Co-L	15.20±6.24	16.24±5.98	14.18±5.32	19.93±6.05[a]	0.020*	0.213
Co-G	22.13±8.91	19.23±11.69	20.56±6.21	18.56±10.81	0.175	0.076
Descending Phase of Dynamic Overhead Squat						
Erector spinae	28.91±5.77	27.80±7.84	30.27±5.28	29.02±6.39	0.365	0.036
Multifidus	25.20±4.05	24.76±4.35	25.82±6.24	27.07±5.65	0.706	0.006
Rectus abdominis	25.81±4.45	24.81±4.45	23.55±4.90	22.42±5.88	0.250	0.051
Transverse abdominis	10.25±2.38	11.36±3.58	10.61±5.25	14.36±4.53[a]	0.016	0.227
Co-L	19.91±6.22	17.69±4.74	18.69±5.32	23.87±5.33	0.298	0.047
Co-G	27.20±7.53	25.31±6.68	26.93±7.36	24.43±7.41	0.167	0.081
Ascending Phase of Dynamic Overhead Squat						
Erector spinae	35.69±4.86	34.65±6.62	33.46±7.32	32.18±5.59	0.511	0.019
Multifidus	30.76±6.63	29.20±5.12	30.20±6.32	31.26±5.29	0.826	0.002
Rectus abdominis	32.37±5.55	31.23±5.29	29.55±6.36	18.80±4.66[a]	<0.001*	0.466
Transverse abdominis	14.12±4.22	15.03±5.68	13.61±4.13	18.48±3.87[a]	0.019*	0.217
Co-L	22.24±8.56	23.58±7.36	20.56±6.25	25.01±5.30[a]	0.015*	0.231
Co-G	30.87±12.43	31.42±10.47	28.31±9.35	26.93±8.23	0.164	0.079

*Significant difference between the groups (P < 0.05); *d*: Partial eta-squared; [a]P < 0.05 pre-test vs. post-test.
Co-L: Co-contraction of local muscles.
Co-G: Co-contraction of global muscles.

Table 3. Two-way repeated measures ANOVA test in single-leg squat test (mean ± standard deviation)

Static Single-leg Squat						
	Control group (%MIVC)		**Training group (%MIVC)**		**Two-way ANOVA**	***d***
Muscles	**Pre-test**	**Post-test**	**Pre-test**	**Post-test**		
Erector spinae	36.80±5.65	34.82±6.86	34.08±6.06	32.83±4.50	0.144	0.090
Multifidus	28.53±3.61	27.20±4.41	30.26±5.59	29.20±4.11	0.089	0.121
Rectus abdominis	30.48 ±6.10	29.48±4.16	28.55±5.77	27.24±2.92	0.162	0.083
Transverse abdominis	17.25±3.41	18.36±2.48	16.73±6.19	23.17±5.89^a	0.015*	0.233
Co-L	24.36±7.42	23.19±4.87	23.01±6.39	24.62±5.34	0.451	0.035
Co-G	24.53±8.13	25.98±7.01	24.81±9.13	25.93±7.32	0.422	0.051
Descending Phase of Dynamic Single-leg Squat						
Erector spinae	29.02±6.48	28.47±6.07	29.08±5.68	28.52±5.24	0.105	0.110
Multifidus	25.20±4.44	24.09±4.32	27.70±5.97	28.57±6.25	0.824	0.002
Rectus abdominis	27.14±5.10	25.70±5.16	25.24±5.36	24.11±5.32	0.059	0.146
Transverse abdominis	15.25±2.88	16.36±3.38	15.48±2.58	23.73±8.60^a	0.013*	0.242
Co-L	26.02±8.13	28.24±7.58	25.12±5.96	32.50±6.19^a	0.018*	0.221
Co-G	28.20±6.62	26.53±7.36	30.43±7.55	28.56±7.69	0.260	0.055
Ascending Phase of Dynamic Single-leg Squat						
Erector spinae	34.47±7.02	33.80±5.07	32.77±7.32	31.64±6.18	0.414	0.029
Multifidus	30.76±5.28	29.98±4.24	31.45±7.20	34.07±6.45	0.146	0.090
Rectus abdominis	23.70±4.69	23.37±4.71	22.92±4.39	21.99±4.53	0.140	0.097
Transverse abdominis	15.80±5.20	14.58±4.75	13.61±5.34	21.11±6.86^a	0.046*	0.163
Co-L	25.47±5.46	23.36±5.73	24.37±5.01	33.12±6.49^a	0.043*	0.166
Co-G	31.09±6.33	29.98±6.14	28.06±7.15	27.12±6.76	0.102	0.112

*Significant difference between groups ($P < 0.05$); *d:* Partial eta squared; $^a P < 0.05$ pre-test vs. post-test.

Results

The activity of the transverse abdominis (t = 3.43, P = 0.004) and co-contraction of local muscles (t = 3.08, P = 0.008) in the static overhead squat, activity of the transverse abdominis in the descending phase of dynamic overhead squat (t = 3.01, P = 0.009), and activity of the transverse abdominis (t = 4.06, P = 0.001), and co-contraction of local muscles (t = 3.22, P = 0.006) in the ascending phase of dynamic overhead squat significantly increased in the training group after RMSIT compared to the pre-test values. The activity of the rectus abdominis significantly decreased after RMSIT compared to the pre-test in the ascending phase of the dynamic overhead squat (t = 4.42, $P < 0.001$). At the end of intervention exercise, significant differences interaction (group × time) were seen in the activity of the transverse abdominis (P = 0.017, d = 0.225) and co-contraction of local muscles (P = 0.020, d = 0.213) in the static overhead squat, as well as, in the activity of the transverse abdominis (P = 0.019, d = 0.217) and co-contraction of local muscles (P = 0.015, d = 0.231) in the ascending phase of dynamic overhead squat, and activity of the transverse abdominis (P = 0.016, d = 0.227) in descending phase of dynamic overhead squat. Also, a significant difference in interaction (group × time) was seen in the activity of the rectus abdominis ($P < 0.001$, d = 0.466) in the ascending phase of the dynamic overhead squat (Table 2).

The activity of the transverse abdominis muscle in the static single-leg squat (t = 3.09, P = 0.007), descending phase of dynamic single-leg squat (t = 3.30, P = 0.005), and ascending phase of dynamic single-leg squat (t = 3.50, P = 0.003) significantly increased in the training group after training compared to the pre-test values ($P < 0.05$). The values of the co-contraction of local muscles significantly increased in the training group after RMSIT compared to the pre-test in the descending (t = 3.15, P = 0.007) and ascending (t = 3.97, P = 0.001) phases of dynamic single-leg squat. The results of the two-way ANOVA showed significant differences in the group × time interaction for activity of the transverse abdominis (P = 0.015, d = 0.233) in the static single-leg squat, descending (P = 0.013, d = 0.242) and ascending (P = 0.046, d = 0.163) phases of dynamic single-leg squat, and the values of the co-contraction of local muscles activity in the descending (P = 0.018, d = 0.221) and ascending (P = 0.043, d = 0.166) phases of the dynamic single-leg squat (Table 3).

The results showed that through RMSIT lumbopelvic motor control in the right (t = 4.06, P < 0.001) and left (t = 4.65, P < 0.001) sides significantly improved in the training group compared to the pre-test values. The results of the two-way ANOVA showed significant differences in the group × time interaction for lumbopelvic motor control in the right (P = 0.033, d = 0.182) and left (P = 0.006, d = 0.290) sides. There was no significant difference in the pre- and post-test pain (P > 0.05). The results of the two-way ANOVA did not show significant differences in the group × time interaction for pain index, but the effect size showed a large value according to Cohen (P = 0.056, d = 0.144).

Discussion

The aim of the present study was to investigate the effect of immediate RMSIT on the activity of selected core muscles, co-contraction of these muscles, lumbopelvic stability, and pain severity in a group of athletes affected by CLBP. To reduce pain and to improve quality of life and return to physical activity, athletes affected with CLBP need to receive rehabilitation services. In addition, return of athletes to optimal performance of exercises should be facilitated.

It should be emphasized that surface EMG device was used to evaluate muscle activity in the present study. The possibility of errors in this technique was high if the unwanted noises were not limited which might be taken into account among the limitations of the given method. However, the aim of the present study was to precisely record muscle activity in a way that it did not affect the interpretation of the results, so urban electricity or other noises were eliminated.

The results of this study demonstrated that RMSIT increased the activity of transverse abdominis as a local muscle. The transverse abdominis muscle is considered as the most important lumbar-pelvic and spinal stabilizer muscle due to its specific anatomical and biomechanical characteristics as well as its connections (31). In patients with CLBP, changes in the pattern of local and global muscle activity results in a decline in transverse abdominis muscle activity and a rising trend in the compensatory activity of the global muscles, which subsequently disrupts the process of maintaining articular stability in these patients (25, 26, 28, 32). The increase in the activity of the local muscle reflected in the EMG is due to changes in the motor units from the random mode before performing the RMSIT to the synchronized mode after respiratory training (33). In synchronized mode, more components are used in muscle activity (33). Since surface EMG device was used to record the electrical activity of the muscles in the present study, it should be pointed out that the surface electrodes reflected the activity of the motor units in muscle tissue (33). The main therapies used for these patients include stabilizing exercises, involving the co-contraction of abdominal muscles and abdominal hollowing. The main goal in all exercises is the optimal use of both local and global muscles (32). Nevertheless, in most training methods, the global muscles are dominant (28). In the present study, the local muscle activity could be increased without significantly increasing global muscle activity.

The findings of the present study also showed a significant increase in the co-contraction of transverse abdominis and multifidus muscles. The increased co-contraction in these muscles resulted in a rise in segmental stability of the spine (7). After fulfilling RMSIT, the nerves of the given muscles, including the thoraco-abdominal ones, were stimulated due to increased muscle load (28). Therefore, after RMSIT and the onset of activation of the muscles and the activity of the motor units, improving the function of the neuromuscular system, which occurs simultaneously, could be effective in terms of increasing the activity of the local muscles (28,34). Recent studies have shown that respiratory muscle training results in increased muscle strength, coordination of core muscles, and more efficient athletic performance (35,36). While doing these exercises, synergistic coordination of respiratory muscle activity is thus required to maintain the thoracolumbar configuration to produce maximum pressure (26). According to the results of this study, the activity of the global trunk muscles was not significant following RMSIT. Since one of the main findings of patients with pain in individuals affected with CLBP is the excessive activity of the global muscles and decline in local muscle activity, the results of the respiratory exercises showed their optimal effectiveness, as an advantage (28).

The results of the present study demonstrated that RMSIT improved lumbopelvic motor control. Muscles that maintain lumbopelvic stability are local muscles of postural, tonic, and segmental stabilizers, such as the lumbar multifidus, pelvic floor, transversus abdominis, and diaphragm (3). Patients with CLBP have decreased lumbopelvic motor control function, such as deep abdominal muscle contraction (28), delayed electromyography onset (37), and the transverse abdominis function (7), compared with individuals without CLBP (3). Lumbopelvic motor control function was compared between patients with CLBP and healthy controls and the prevalence of CLBP according to core stability function was investigated. The results showed that patients with CLBP had decreased lumbopelvic motor control function. They attributed the impairment in lumbopelvic motor control to the weakness of the local muscles of core region. In the present study, by improving the activity and co-contraction of local muscles in core region like the transverse abdominis and multifidus and increasing segmental stability, lumbopelvic motor control improved. Impaired motor control is a risk factor for musculoskeletal injury and recurrence of CLBP (28). Therefore, injury and recurrence of CLBP can be prevented by improving the control motor.

The results of the present study showed that RMSIT from statistical point of view did not show a significant reduction in the pain index, but the large value of the effect size (d>0.14) showed a clinical effect of RMSIT on the pain index. In addition, other studies (25, 26,) showed that respiratory muscle training reduced CLBP. It is possible to reduce the pain by increasing the segmental stability and lumbopelvic stability (3,25). The limitation of the research was that, although in the present study, all processes were exactly controlled by the therapist, and verbal feedback was provided by her, it was not possible to control 100% of the regularity of respiratory exercise. Another limitation is that immediate RMSIT was used in this study and it needs long-term follow-up.

Conclusion

The results of the present study revealed that immediate RMSIT could improve the activity and co-contraction of local muscles in the core region, which have a major role in individuals with CLBP. Also, immediate RMSIT increasing the lumbopelvic motor control. Therefore, RMSIT could play an important role in activating the trunk local muscles and lumbopelvic stability. Further studies are needed to prove the effect of these exercises on the core muscles activity and increasing lumbopelvic stability in athletes with CLBP.

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Authors’ contributions

Conception and design, Leila Ahmadnezhad; analysis and interpretation of data, Behnam Gholami-Borujeni; revision and editing work critically for important intellectual content, Ali Yalfani; monitoring progress, Ali Yalfani; final approval of the study, Leila Ahmadnezhad, Ali Yalfani, Behnam Gholami-Borujeni.

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Conflict of interests

The authors declare that there is no conflict of interests.

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