Research Paper

Effect of Fatigue on the Core Muscle Endurance in Female Athletes With and Without Non-specific Chronic Low Back Pain

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ABSTRACT

Purpose: Non-specific chronic low back pain (LBP) is the most common type of chronic LBP and a common debilitating condition, especially in athletes, that can also affect performance. The core muscles are necessary to create a stable level of support for sports performance and appropriate movements of all organs, and its deficiency is related to complications, such as LBP. This research aims to investigate the effect of a fatigue protocol on core muscle endurance in athletes with and without non-specific chronic LBP.

Methods: A controlled laboratory study was conducted; 42 female athletes with and without non-specific chronic LBP were selected through convenience sampling method and divided into two groups with non-specific chronic LBP and without non-specific chronic LBP. McGill's core endurance test was used to measure core muscle endurance. The measurements were done before and after the implementation of the functional core fatigue protocol (FCFP). SPSS software, version 22 and dependent t-tests and analysis of covariance (ANCOVA) were used to evaluate mean differences obtained in the two groups. The significance level was considered 95%, and the α level was ≤0.05.

Results: The analysis of covariance (ANCOVA) showed a significant difference between the two groups with and without non-specific chronic LBP after performing the functional core fatigue protocol (FCFP) in McGill's test scores in isometric flexion exercise (P=0.001), isometric extensor exercise (P=0.001), right side bridge (P=0.001) and left side bridge (P=0.001). In the post-test measurement, the endurance of the core muscles decreased in the LBP group.

Conclusion: The findings revealed that fatigue can affect the core stability and reduce the core muscles endurance of female athletes with non-specific chronic LBP. Therefore, core muscle weakness can be recognized as a risk factor for chronic LBP, and in order to prevent this damage, it is recommended to strengthen this area in rehabilitation programs.

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Highlights

• Female athletes with non-specific chronic low back pain had weaker core muscle endurance than healthy athletes.

• Fatigue can have an adverse effect on the core stability of the body.

• Core muscle endurance of Female athletes with non-specific chronic low back pain showed a significant decrease after the fatigue protocol.

Plain Language Summary

Low back pain is a common problem and more than 80% of people, whether athletes or non-athletes, will suffer from it at least once in their lifetime. Non-specific chronic low back pain is a type of back pain that does not have a specific structure and there is no specific organic damage that can explain the cause of the pain. There is a set of muscles in the abdominal area, the ability and endurance of which are necessary to maintain the stability of the whole body. The occurrence of back pain can cause a series of muscle weakness in the central area of the body. Based on this, it is necessary to evaluate the endurance of the abdominal muscles because of their very effective role in preventing or putting the athlete at risk of injury, as well as preventing the recurrence of back pain.

1. Introduction

Low back pain (LBP) is a common debilitating condition and a crucial clinical, social, and economic problem. Epidemiological studies show that 70%-85% of the population suffers from LBP at least once in their lifetime, and about 80% of them report recurrence [1, 2]. Several classifications have been proposed for LBP patients. Some researchers classify LBP according to the duration of the symptoms, with up to 6 weeks after the onset as acute LBP, from 6 weeks and 3 months as sub-acute, and for more than 3 months as chronic [3]. In 85% of patients with chronic LBP, no specific cause for LBP can be found, and this wide range of patients is divided into non-specific chronic LBP [4].

Today, with the increase in people's participation in sports activities, the occurrence of sports-related injuries, including LBP, has also increased [5]. Bono et al. reported the prevalence of LBP in athletes from 1% to more than 30%, which can be affected by the type of sport, gender, training intensity, number of training sessions, and technique [6]. The amount of low back injuries encompass about 10%-15% of all athletes' injuries and mainly include the soft tissues around the spine [7]. The crucial issue regarding LBP is its chronicity, which remains a problem and incurs a lot of treatment costs every year and can cause athletes to lose the opportunity to train and compete and reduce their performance, making them prone to chronic and severe injuries [8]. It has been reported that LBP is one of the common causes that makes athletes miss training and competitions due to pain and movement and performance disorders [7]. Regarding LBP, one of the main goals of researchers is to find a suitable treatment method for each LBP group [9]. However, the successful control of LBP depends on exact scientific determination and explanation; in other words, the LBP cause must be identified first, and then treatment should be focused on.

During the last decade, core stability has become a fundamental issue in sports medicine, where its deficiency causes complications, such as LBP [10] and sports injuries [11]. Core stability is a foundation for athletic performance and health. The core region is defined as "proximal stability for distal mobility" [12]. The proper functioning and coordination of the core muscles are necessary for the proper production, transfer, and control of the forces and movements that occur in the body. Weakness or decline in the coordination of the core muscles can lead to abnormal movement patterns, compensatory movement patterns, and increased pressure and loads on the spine; its dysfunction causes LBP and limb injuries in athletes [13]. One of the crucial factors that cause instability in the spine is a change in the structure and incorrect and inappropriate function of the muscles in the core region, which leads to muscle weakness, dysfunction, fatigue, and LBP [14]. According to Oliver, core stability takes a more complicated form in athletes due to the difference in the needs of a normal person and an athlete [15].

Many parameters are involved in core stability that directly or indirectly affects it, and we better understand core stability if we know the parameters contributing to the core stability better and their defect which may disturb the core stability. In a review study, Waldhelm divided core stability evaluation tests into strength, endurance, performance, flexibility, and motor control [16].

It is essential to note that if there are risk factors that make the athlete prone to back injuries, including LBP, the athlete will be at risk of recurrence unless those risk factors are identified and preventive measures are taken. The review of studies shows that little research has been conducted concerning the evaluation of mechanical factors, such as core stability on LBP in athletes. Most studies have been conducted in the field of pathological factors affecting LBP; besides, not sufficient studies have been carried out on the effect of fatigue on the core stability muscles concerning the negative impact of fatigue on the core stability components. In this regard, Kibler has suggested assessing the relationship between core stability and sports performance during fatigue to obtain more information about its nature [17]. It has been demonstrated that the ability, weakness, and overall performance of muscles are better determined during fatigue [18]. Functional tests have a greater ability to evaluate muscle function during fatigue than ordinary time. Therefore, the use of these tests in fatigue conditions is also recommended [18]. Evidence shows that the evaluation of the effect of core muscle fatigue on core stability indices can provide valuable information about how core stability is related to muscle function and musculoskeletal pain, including LBP. Fatigue is a factor that can reduce the coordination and function of muscles. Since core muscles are required for the creation of a stable level of support to perform movements proportionate to the body organs, their fatigue may affect muscle function, especially in athletes with LBP. In this regard, Abbott et al. investigated the effect of a core muscle fatigue protocol on pedaling mechanics in 15 professional cyclists and concluded that core muscle fatigue changed the pedaling mechanics of their lower limbs. He believes that these changes may lead to knee injury because the knee joint is exposed to more pressure after the core muscles fatigue [19]. McMullen et al. showed that the fatigue of the gluteus medius muscle as a core stabilizing muscle decreases static and dynamic balance as well as the movement quality in non-athletic overweight men [20]. Vuillerme et al. also reported that fatigue of trunk extensor muscles reduces postural control in healthy young people [21]. However, this limited number of studies has not considered the effect of core muscle fatigue on core stability indices, such as strength and endurance of LBP patients. On the other hand, Puntumetakul et al. proved that core stability exercises for patients with non-specific chronic LBP can improve joint position sense, and reduce pain and functional disability [22]. Therefore, core stability is somewhat related to LBP.

It is essential to evaluate core stability in athletes with LBP, assuming the prevalence of LBP in athletes, a large number of athletes, at risk of LBP recurrence, the role of core stability in preventing or putting athletes at risk of injury, and the effect of core stability on the performance of athletes. Athletes always seek to increase their performance and use preparation programs to achieve this goal, one of which is exercises related to the core muscle area. Since the core trunk is the main part of the whole body, it is necessary to have the best performance in terms of various indices. During the last decade, core stability has become a fundamental issue in the field of sports medicine, the deficiency of which causes complications, such as LBP [10]. Therefore, it is necessary to mention it as a risk factor in the occurrence of LBP and evaluate it from different aspects. The literature review shows that no research has been conducted to assess core muscle endurance after a fatigue protocol among athletes with and without non-specific chronic LBP. Studies show that the cumulative negative effects of fatigue on neuromuscular control, especially in athletes and during competitions, can cause risky movement strategies and increase the probability of injury [23]. Also, since the fatigue phenomenon is present in most training and rehabilitation phases of athletes with LBP, fatigue is an inevitable component in the training and rehabilitation program of athletes with LBP. Therefore, it is necessary to investigate the impact of fatigue as a risk factor on the risk of developing non-specific chronic LBP. Therefore, the current study was conducted to investigate the effect of fatigue on core muscle endurance in athletes with and without non-specific chronic LBP.

2. Materials and Methods

A controlled laboratory study was conducted in two groups with and without LBP. The sample size was determined based on Nipa et al.'s previous study on non-specific chronic LBP samples using G*Power 3.1 (G*Power Software Inc., Kiel, Germany). [24]. In the G*power software, analysis of variance (ANOVA) was used for power analysis to detect the significant difference in the mean values of two groups with an average effect size of 0.37. Power was set at 0.80 with an α level of 0.05. Therefore, to detect a significant difference between the two groups, a sample size of 41 participants was required. Therefore, 21 patients were assigned to

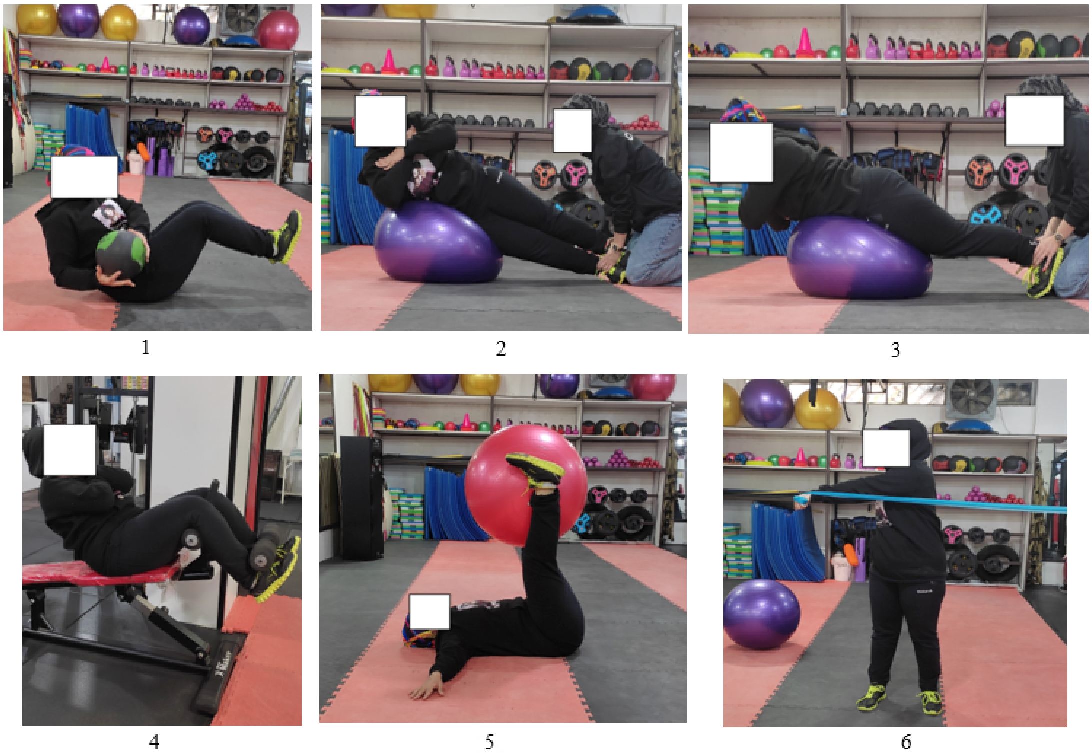

Figure 1. Fatigue protocol

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each group; 21 subjects with non-specific chronic LBP (age values Mean±SD 28.42±2.69, height: 163.28±6.77, and weight: 62.71±8.08) and 21 subjects without non-specific chronic LBP (age values Mean±SD 28.14±2.43, height: 163.28±6.77, and weight: 60.52±7.26) (Table 1). Based on the inclusion and exclusion criteria, they were divided to two groups with and without non-specific LBP. The inclusion criteria included women with a history of three years of regular exercise and at least three sessions a week, suffering from LBP at least in the last three months [25] (related to the LBP group), having a history of LBP three times in the last year, each lasting for a week [25] (related to the LBP group), and having pain intensity of 3-7 on the visual analogue scale (VAS) [26]. The exclusion criteria included a history of surgery in the upper, and lower limbs and the spine, any acute injury in the past 60 days, LBP caused by factors, such as metabolic diseases, rheumatic diseases, severe joint destruction, infections, fractures, herniation of intervertebral discs, malignancies, or anatomical abnormalities, lack of consent to continue taking part in the study, pain during the tests such that the person feels unable, and lack of participation in the post-test. All the stages of the experiments were performed in the corrective movements laboratory of the Faculty of Physical Education and Sports Sciences of the University of Tehran.

At the beginning of the study, all issues, including objectives, possible risks, complications, and timing were fully explained to all subjects. The participants entered the study with full awareness and signed the relevant form. Ethical considerations and compliance with ethical guidelines, and all ethical principles were observed. First, the demographic characteristics of the subjects, such as pain history, number of repetitions and their intensity, age, height, weight, and anthropometric measurements were evaluated and recorded. To measure the pain, visual analogue scale (VAS) was used [27]. In this method, the sample is asked to mark the point that is the best descriptor of her current pain intensity on a 100 mm long graduated ruler, where 0 represents the pain-free state and 100 represents the worst possible state of pain tolerated by the person. The distance from the marked point to the left end of the line is measured in millimeters, and we make a numerical value that can also be recorded; thus, this number is recorded as the patient's pain intensity. To perform the test, each subject was measured twice. The first session was implemented to perform the tests under normal conditions (without fatigue). The second session was conducted with an interval of at least 48 h after the first session, the purpose of which was to perform the tests on the fatigue state of the core muscles. At the beginning of the second session, the subject warmed up for 15 minutes and then participated in

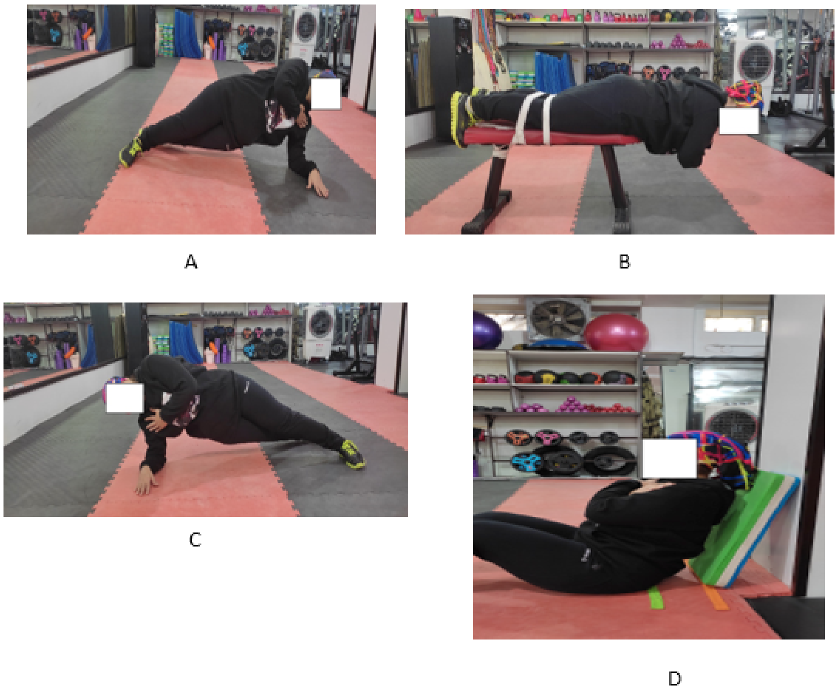

Figure 2. McGill's protocol

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the fatigue protocol of the core muscles; afterward, they performed the tests immediately. The functional core fatigue protocol (FCFP) derived from the fatigue protocol of Abt et al. was used for the fatigue of the core stabilizing muscles in all movement planes [19]. The excellent intra- and inter-test validity of this protocol (ICC=0.825, ICC=0.981) regarding central muscle fatigue has been confirmed [19]. The protocol duration is 24 minutes and includes four consecutive sets of six exercises so that the subject performed each set of exercises for 40 s and rested for 20 s between the two exercises. The subjects participated in a 10-minute warm-up before performing the protocol. Each set includes six exercises in the following order (Figure 1).

Seated upper torso rotations with medicine ball (2 kg)

Seated, similar to the sit-up, sit on the floor and lift your feet off the floor. Hold a 2 kg medicine ball with both hands and stretch your arms in front of you. With a strong and energetic movement, turn your body and the ball to one side and then return to the starting position. Then, do this movement for the other side of your body as well.

Lateral side trunk flexion with weight plate (2 kg) on a Swiss ball

To start, place the left half of the body on a Swiss ball (waist, hip, and upper thigh on the ball). Cross your legs on the floor and ask someone to hold them on the floor. Hold the weight plate with your hands on your chest. You are now in the starting movement position. While exhaling, lift your torso from the side by bending your back. Maintain the contraction for a second and slowly return to the initial position by inhaling. Repeat the movement for the recommended number of times. Repeat the movement on the other side of the body.

Rotating lumbar extension with weight plate (2 kg) on a Swiss ball

To start, lie on your stomach on a Swiss ball while pushing the ball with your hips. Place the tip of the toe on the ground and ask someone to hold your feet so that they do not leave the ground when you move and your balance is maintained better. Bend the body from the hips so that the upper trunk is parallel to the ground. Hold a 2 kg weight in front of your chest; bending the body from the hip area, slowly moving your upper trunk up. Remember that this part of the movement should be accompanied by exhalation (breathing out). At the highest point of the

Table 1. Anthropometric characteristics of groups with and without non-specific chronic LBP

Group	Mean±SD			
	Age (y)	Weight (kg)	Height (cm)	BMI (kg/m²)
Non-specific LBP	28.42±2.69	62.71±8.08	163.28±6.77	23.55±2.93
Without non-specific LBP	28.14±2.43	60.52±7.26	163.80±6.31	22.56±2.54

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movement, pause for a moment, and then return to the starting point while inhaling. Repeat this movement.

Incline sit-ups with weight plate (2 kg)

To start, lie on your back on an inclined table and fix your feet on the mat. Hold a 2 kg weight plate with your hands crossed on your chest. Press the lower back (quadratus lumborum) towards the table to start the movement. By contracting the abdominal and pelvic muscles, bring the upper trunk up to create a full contraction. This part is the positive phase of the movement and exhales in this phase. Slowly return to the starting point. This part is the negative phase of the movement and inhales in this phase. Repeat the movement for the specified time according to the protocol.

Supine lower torso rotation with a Swiss ball

Lie on the floor and open your arms to the sides to form your body in the shape of a cross. Stretch your legs and place a Swiss ball between them. Then, raise the legs until they are vertical to the floor. Keep the pelvis and hips fixed on the floor, and then lower the legs slowly while controlling the ball and return to the starting position to put pressure on your abdominal muscles. Repeat this movement.

Standing torso rotations using a blue resistance band

Adjust the resistance band to shoulder height and attach it to a sturdy object (or an adjustable cable pulley). Hold it with one hand. The other hand is kept next to the body. Spread your legs shoulder-width apart. Stand with your hand outstretched and perpendicular to the cable or resistance band and far enough away from the device to apply pressure to hold the cable. With a rotating movement from the abdominal belt, rotate towards the device and pull it to the opposite side. During this movement, your legs should be fixed. After completing the set, perform the movement with the opposite hand.

McGill's protocol was used to evaluate the core muscles' endurance [28]. The previous studies show that these tests have an excellent validity coefficient. The intra-group correlation coefficient of the isometric flexion exercise is 0.97, the isometric extensor exercise is

Table 2. The results of the covariance test to investigate the difference between two groups with and without non-specific chronic LBP

Variables	Task	Group	Mean±SD		F	Sig.	Eta Square
			Pre-test	Post-test			
Core endurance time	Flexor	Without LBP	57.71±11.76	52.38±11.11	13.419	0.001*	0.256
		LBP	54.19±13.50	40.52±15.26			
	Extensor	Without LBP	114.38±23.4	96.14±26.50	14.388	0.001*	0.270
		LBP	89.28±17.54	55.57±17.29			
	Side bridge, right	Without LBP	62.60±8.41	58.25±8.20	23.789	0.0001*	0.379
		LBP	46.85±13.58	32.33±14.76			
	Side bridge, left	Without LBP	61.42±7.96	55.80±9.02	23.873	0.0001*	0.380
		LBP	44.38±11.20	30.90±9.92			

*Significance at P>0.05 level

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0.97, and the side-bridge exercise is 0.99 [8]. According to Figure 2, this protocol includes four tests that measure core muscle endurance (isometric flexion exercise [D], isometric extensor exercise [B], and side-bridge exercise [C]). A hand-held timer was used to record the duration of the isometric posture maintained by the subjects. Each test was measured once, and a 3-minute break was considered for each test.

To analyze the data, SPSS software, version 22 was used. The Shapiro-Wilk statistical test was used to check the normality of the data, and the Levene test was used to check the homogeneity of the variables. Also, analysis of covariance (ANCOVA) was used to assess inter-group differences. The significance level was considered P≤0.05.

3. Results

Table 1 presents anthropometric data of women with and without non-specific chronic back pain.

According to the results of the Shapiro-Wilk test, the data distribution of all research variables was statistically normal (P>0.05). Therefore, parametric statistical tests were used to analyze the data.

To compare the effect of fatigue on the muscular endurance of people with and without non-specific chronic LBP, ANCOVA was used to determine inter-group differences in the post-test (Table 2).

The ANCOVA after adjusting the results based on the covariate variable (results related to the tests before fatigue) showed a significant difference between the two groups with and without non-specific chronic LBP in the variables of muscle endurance in isometric flexion exercise, isometric extensor exercise, right-side bridge, and left-side bridge (P<0.05). The non-specific chronic LBP group in (isometric flexion exercise (42.05±1.69), isometric extensor exercise [66.27±3.31], right-side bridge [1.81±38.72], and left-side bridge [37.63±1.45]) showed lower endurance compared to the group without non-specific chronic LBP (isometric flexion exercise [50.85±1.69], isometric extensor exercise [85.44±3.31], right-side bridge [52.37±1.81], and left-side bridge [49.07±1.45]).

4. Discussion

The results indicate the negative effect of fatigue with a moderate effect size on endurance tests of trunk flexor muscles (0.256), trunk extensor muscles (0.270), and right and left side (0.379, 0.380, respectively) in athletes with non-specific chronic LBP compared to the group of healthy athletes. In other words, the athletes of the non-specific chronic LBP group showed significantly less muscle endurance in all four evaluated directions compared to the group without LBP. The findings should inform health professionals to pay more attention to the functional status of trunk muscles in athletes, which can be integrated with the existing injury prevention programs and rehabilitation protocols for sports-related low back injuries. Many sports-related injuries may be attributed to muscle defects, such as weakness and poor endurance [29]. Research has shown that first, a correct understanding of the diagnosis of related factors should be provided to heal LBP in chronic LBP patients [30]. The results revealed that core muscle endurance is one of the factors related to chronic LBP; in these patients, muscle endurance in this area significantly decreased after a fatigue protocol.

Physical examinations are often performed as a major component of injury risk reduction screens to identify potential risk factors. Several activities have been identified as potential screening tools because no standardized method exists to quantify trunk muscle endurance. In 1999, McGill et al. supported the use of McGill's core endurance tests to evaluate trunk muscle endurance, especially in patients with LBP [28]. Published normative data for isometric endurance of trunk flexors and extensors using anterior and posterior tests (Sorensen) in novice athletes with a mean age of 21 years are 136 and 161 s, respectively. The mean endurance time for the right and left side plank is 95 and 99 s [31]. The scores recorded for the McGill core endurance tests in all directions were significantly lower in the subjects of both groups.

The present results are consistent with the findings of Sung, who reported increased fatigue of low back-pelvic muscles in patients with LBP [32], and with the results of Da Silva et al., who concluded that people with non-specific LBP have significantly low back muscle fatigue compared to people without non-specific LBP, measured by electromyography [33]. Moreover, Correia et al. showed that tennis players with non-specific LBP showed less activity in the erector spinae and longissimus thoracis muscles and lower co-contraction patterns and lower abdominal muscles endurance compared to healthy players without LBP symptoms [34].

Proper functioning of the core stabilizer muscles minimizes compressive, propulsive, and shearing forces to ensure optimal force distribution and maximum power delivery. Decreased core muscle endurance is a major risk factor for LBP among athletes at risk of increasing LBP, usually due to the loads that athletes put on their spines following complex asymmetric and repetitive movements. In this regard, Watanabe et al. reported that baseball athletes whose core muscles did not have sufficient stability showed a higher probability of reporting LBP during various movements, especially back extensions. The core stability was evaluated using the Sahrmann core stability test [35].

Consistent with the current results, Abdelraouf et al. investigated the relationship between core muscle endurance and low back dysfunction in university male athletes with and without non-specific LBP [36]. Thirty athletes with non-specific LBP and 25 healthy athletes were evaluated using McGill's anterior, posterior, and left and right plank core endurance tests (s) and for dysfunction using the Micheli functional scale. The results of this study suggest that poor core muscle endurance is likely associated with non-specific LBP in collegiate athletes. They recommended that injury risk reduction and low back management programs for the athletic population should include strategies that emphasize core muscle endurance, particularly trunk flexor and extensor muscles. Vanti et al. measured the core endurance and instability with the amount of pain and disability in patients with LBP and declared that the amount of core endurance and stability decreased in patients with LBP, and an increase in the anterior and posterior core muscles endurance reduced pain in these patients [37].

It has been shown that athletes with poor trunk muscle endurance may easily injure the passive and pain-sensitive structures of the lumbar spine, which ultimately affects physical performance. Also, early loss of core control due to fatigue may lead to aberrant or excessive intervertebral rotational and translational movement [38]. During physical activities, the core muscles of the trunk provide both mobility and stability of the lumbopelvic region. Changes in the trunk muscles activity, such as poor or insufficient motor control, observed in the participants with non-specific chronic LBP, may increase motor dysfunction and result in less than optimal sports performance.

The multifidus, transversus abdominis, and abdominal oblique muscles are the first muscles to suffer dysfunction when LBP occurs. Since these muscles direct the joint in different movement patterns and functions caused by these different patterns, their weakness causes defects in joint function and eventually functional movement disabilities. Therefore, the aforementioned muscles need to be retrained. In other words, according to the results, when LBP occurs, weakness occurs in the core muscles, instability in the spine, and the risk of injury in this area increase, therefore focusing on promoting the core muscle endurance can increase the fatigue threshold, strength, coordination, static and dynamic stability, and eventually reduce pain [39, 40].

The findings manifested that chronic non-specific LBP is probably associated with the change in motor coordination and increased trunk muscle fatigue. Therefore, delays in the activation of dominant trunk muscles can create defective movement patterns that cause instability and excessive joint movement, accompanied by an increased risk of dysfunction and pain. Also, this significant effect of fatigue showed a decrease in the level of muscle tolerance of stabilizing muscles, such as multifidus, transversus abdominis, abdominal oblique, and erector spinae in the group with non-specific chronic LBP. Several studies have investigated the effects of fatigue on muscle performance. In this regard, Gribble and Hertel found a significant relationship between gluteal muscle fatigue and loss of balance and stated that thigh abductor muscles' fatigue leads to defects in balance control [41]. After causing fatigue in the lower limbs and trunk, Cetin et al. stated a significant difference between static balance before and after fatigue and is affected by fatigue [42]. Vuillerme et al. conducted a study on 15 students and exerted fatigue in their trunk extensor muscle; they revealed that trunk muscles fatigue reduced their balance and posture control [21].

Coulombe et al. investigated the short-term effect of core stability exercises compared to general exercises on athletes with chronic LBP and found that, in the short term, core stability exercises were more effective than general training in reducing pain and increasing specific functional low back status of patients with LBP [43]. Hence, core muscles and chronic LBP are correlated. Momeni et al. emphasized the endurance of the trunk flexor and extensor muscles with therapeutic exercise. Also, they believed that fatigue affects people's general ability and makes them prone to injury even when faced with high pressure. Excessive fatigue leads to the loss of control, accuracy, and delicacy of individuals' actions and movements, predisposing the occurrence or development of LBP [44]. Shinkle et al. considered core muscle weakness to be effective in creating a weak and unstable foundation as a predictor of lower limb injuries [45]. Since people with non-specific chronic LBP have muscle dysfunction, the negative effects of fatigue on muscle endurance and function and effective factors on the performance of the core muscle endurance test seem logical. Despite its strengths, this study is not without its limitations, including instrumental limitations, such as the lack of digital devices with higher validity and precision, such as electromyography, for a more comprehensive examination of the amount of abdominal muscle force in the process of the fatigue task, assuming the limited number of diagnostic centers and athletic and female subjects, the results cannot be generalized to the general population of patients with non-specific LBP. Therefore, further similar studies are recommended to evaluate the activation moment of different core muscles in athletes with and without non-specific chronic LBP by electromyography. Also, similar studies are recommended to compare the effect of fatigue on some functional indices of core stability in male athletes with and without non-specific chronic LBP and compare it with the current results on women. In addition to comparing muscle endurance, it is also suggested to examine different aspects, such as muscle strength, motor control, and the motion range of the core muscles in athletes with acute LBP and non-specific chronic LBP.

5. Conclusion

It is approved that the core muscles, as one of the vital muscles of the body, critically influence the body structures and many musculoskeletal disorders. The present findings demonstrated that chronic LBP plays a significant role in reducing muscle endurance. After the fatigue intervention, the core muscle endurance of people with non-specific chronic LBP reacted faster and showed weakness. Therefore, the core muscles of people with chronic non-specific LBP should be considered. To increase stability and prevent and correct other complications, injuries, and problems caused by these weaknesses in people with chronic non-specific LBP, related exercise protocols should be included in their exercise program to reduce clinical symptoms and increase the muscle fatigue threshold in the core muscles of non-specific chronic LBP patients. Although the difference reported in this research cannot be determined as the cause or consequence of low back injuries in athletes, it enables sports therapists to design more suitable exercise programs for athletes to prevent or rehabilitate LBP based on these findings.

Ethical Considerations

Compliance with ethical guidelines

All ethical principles are considered in this article. The participants were informed of the purpose of the research and its implementation stages. They were also assured about the confidentiality of their information and were free to leave the study whenever they wished, and if desired, the research results would be available to them. A written consent has been obtained from the subjects. Principles of the Helsinki Convention was also observed.

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Authors' contributions

All authors contributed equally to the preparation of this article.

Conflict of interest

The authors declared no conflict of interest.

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