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The effect of core muscle fatigue on the functional movement screening scores in female athletes

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Abstract

Background: The functional movement screen is developed to examine individual's movement patterns through seven functional tasks.

Aim: This study was conducted to examine the effect of core muscle fatigue on functional movement screening (FMS) scores in female athletes.

Materials and Methods: The study has a pre-test-post-test design. The statistical population included female athletes (18-28 years old) in Tehran with at least two years of sports experience (3 days a week), of which 40 were selected as samples. In this study, core muscle fatigue was examined using the Plank test, before and after which the subjects performed the FMS test. After ensuring the normal distribution of the data through the Shapiro-Wilk test, the effect of core muscle fatigue on the FMS test was examined using Wilcoxon and paired t-tests, and Cohen's D measure was used to evaluate the effect size. The data were analyzed through SPSS 24 software. The significance level in all tests was $P \leq 0.05$.

Results: According to the results, core muscle fatigue significantly decreased the scores of the deep squat (P=0.001), hurdle step over (P=0.002), in-line lunge (P=0.001), stability push-up (P= 0.001), and rotary stability tests (P= 0.001) but did not significantly affect the scores of the shoulder mobility (P=0.317) and active straight leg raise (SLR) tests (P=0.763). Moreover, core muscle fatigue affected the total score of the FMS test (P=0.001), with the average score decreased by 4.32 after applying the fatigue protocol.

Conclusion: Core muscle fatigue significantly reduced the FMS test scores with a medium to large effect size in female athletes.

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1. Introduction

Sports and physical activity have become an integral part of modern life, with people engaging in them regularly. Performing physical activity has increased the occurrence of sports injuries. So, attention to injuries has increased with the growing importance of sports at all levels of society [1, 2, 3]. In the field of medicine and rehabilitation, the core is recognized as the basis and driving force of all movements of the lower and upper limbs and is referred to as the "powerhouse" [4]. Core stability is recognized in rehabilitation, and comprehensive core strengthening is introduced as a way to reduce musculoskeletal disorders and improve athletic performance [5]. Core stability can be defined as the capacity of the lumbar-pelvic-hip muscles' complex to control lower trunk movement and maintain the stability of the vertebral column after skeletal perturbation [6]. It refers to the neuromuscular ability of a set of body muscles (core stabilizing muscles) to control the forces applied to the lumbar spine and pelvic girdle to maintain body stability. The function of the organs depends on the proper core stability [5].

According to Kibler et al. (2006), core stability is the ability to control the position and motion of the trunk over the pelvis to allow optimum production, transfer, and control of force and motion to the terminal segment in integrated athletic activities [5]. The inefficiency of the core can negatively impact individual performance and increase the likelihood of injuries [1]. Deficiency of trunk muscle activation may lead to poor sports performance. Additionally, trunk muscle dysfunction puts athletes at risk of injury in every movement [7].

Athletes need adequate balance, core stability, and neuromuscular control to safely and effectively perform essential sports movements [8]. The core is a complex structure composed of several muscle groups. In the front and sides, it includes the abdominal muscles. At the back, it includes the paraspinal and gluteal muscles. The diaphragm forms the roof of the core, while the pelvic floor and hip girdle muscles form the floor. All these muscles together create stability in the spine, pelvis, and lower limbs [9]. According to previous studies, girls tend to have lower core strength compared to boys, which can lead to increased instability [9]. The feedforward mechanism of the core muscles indicates that these muscles are activated before the start of any movement regardless of the movement direction [10]. Core stability can probably increase the ability of athletes to maintain balance in various dynamic movements and help with the production of appropriate force and control of the middle parts of the body to prevent injury [11]. Core stability is an important element for the proper functioning of organs. It functions in various ways during different activities, including increasing force production and reducing joint loads [12].

Given the crucial role of these muscles in the body and their performance and coordination in executing all activities, the strength, balance, and movement of the core must be carefully controlled [13]. Previous studies suggest that if the upper and lower body muscles are strong, but the core muscles are weak, the force production in the upper and lower limbs will decrease, leading to weak and inappropriate movements [13, 14]. In addition to weakness, fatigue or reduced coordination between these muscles causes inappropriate or compensatory movement patterns, resulting in sports injuries [15].

Various factors can negatively affect neuromuscular motor control. One of these factors is fatigue, which leads to a decrease in muscle coordination and performance [15]. Studies have introduced fatigue as an exercise-related phenomenon that reduces performance [16]. Muscle fatigue is one of the factors that can increase the probability of injury due to a defect in stability and decrease athletic performance [17]. According to the results of the previous studies, muscle fatigue in all sporting activities can lead to disruption in balance and movement patterns [18]. Fatigue has been shown to lead to rapid loss of balance and reduced balance performance in athletes [19]. Functional performance tests have a greater ability to evaluate muscle function during fatigue compared to testing under normal, non-fatigued conditions. Therefore, these tests have been suggested to be used in fatigue conditions [20]. Functional performance tests are physical tests that are performed for various purposes, including determining an athlete's level of ability to participate in a specific sport or occupation, safely returning to activity, and performing movements at all three planes of movement. These tests also evaluate the actual performance of athletes in various factors such as strength, power, speed, agility, and flexibility [5]. It can be argued that these tests measure the overall performance of athletes and are often similar to their daily activities [21].

Researchers have recently introduced various assessment tools and tests to examine more comprehensive movement and performance patterns. These tools and tests are focused on evaluating comprehensive movement patterns to prevent injury. One of these tests is the functional movement screening (FMS) test, which can show the quality of performing functional movement patterns and identify individuals at risk of injury or movement dysfunction [22]. People with scores of 14 or less are at high risk of injury [23]. Changes in movement patterns create compensatory movement patterns that can cause muscle strain, overuse injuries, and damage in general. Athletes with good athletic performance may even be exposed to injury due to poor movement performance [24].

Studies indicate that most injuries in sports occur at the end of the competition or training [25], suggesting the negative effects of fatigue at the end of training or competition on neuromuscular control, which causes injury [26]. Fatigue may have a cumulative and adverse effect on neuromuscular control, especially in the final stages of competition, and may potentially lead to dangerous movement strategies [27]. Furthermore, the movement patterns of girls and boys are different due to the structural differences in their bodies, and the prevalence of sports injuries in girls is higher than boys [28]. This negative effect is important in terms of injury prevention because muscles have multiple roles, including reducing shock forces, reducing bone bending forces, and increasing joint stabilization. The body is protected from injuries if the muscles perform their tasks well. Any change in muscle performance caused by fatigue reduces the ability of muscles to prevent sports injuries [9].

One of the main goals of athletes is to increase and improve their performance. Studies have shown that one way to improve performance is to use core stability exercises. So, the core components and performance should be considered [29]. Studies on the effects of fatigue suggest that this factor reduces the reaction time, the proprioception and the ability to produce power and coordinate movements, all of which can cause a decrease in athletic performance [30]. The effect of core muscle fatigue on the movement pattern of male athletes has been investigated only in one study by Ghorbani et al. The fatigue protocol used by these researchers, as well as the age, gender, and training experience of their participants, differed from those in our study [31]. To the best of our knowledge, no study has investigated the effect of core muscle fatigue on FMS tests in female athletes. Due to the kinetic and kinematic differences between female and male athletes, it is important to investigate the effect of fatigue on the scores of FMS tests in female athletes.

2. Materials and Methods

2.1. Participation

The data were collected using a field method with quantitative measurements. The statistical population included female athletes aged 18 to 28 years in Tehran, all with at least two years of sporting experience (training 3 days a week) in 2023. The sample size was determined to be 40, based on previous studies, e.g., Stracciolini et al. (2014) [28]. G*Power software was also applied to calculate the sample size.

2.2. Instrument

The athletes were selected using purposive sampling based on inclusion and exclusion criteria. The inclusion criteria were being female gender, having active training at least three days per week [32], having at least two years of sporting experience, and being in age range of 18-28 years. The exclusion criteria were having obvious postural abnormalities in the upper and lower limbs, having a history of surgery in the upper and lower limbs in the past six months, having a history of any acute injury in the past 60 days, and being in the follicular phase of the menstrual cycle. The pre-test was conducted first, during which all subjects completed the FMS tests. Following this, a fatigue protocol consisting of plank exercises was performed, and finally, a post-test was conducted.

2.3. Procedure

A meeting was held with the managers of clubs in Tehran about how to conduct the study and its objectives, with brochures and advertisements posted online to select subjects. This study was conducted based on human ethical standards in accordance with the declaration of Helsinki. Informed consent forms were used to ensure that the athletes consented to participate in the study. Data on subjects' age, height, weight, education, dominant hand, dominant leg, body mass index, amount of physical activity per week, sports field, and sports records were collected using data registration forms.

Pre-test FMS assessments, including deep squat, hurdle step, in-line lunge, shoulder mobility, trunk stability push-up, active straight leg raising, and rotary stability, were then performed [33]. If the tests were performed correctly without compensatory movements, the subjects were given a score of 3, and if the tests were performed with compensatory movements, they were given a score of 2. The subjects were given a score of 1 if they could not perform the movement, and no score was assigned if they experienced pain during the movement or the clearing test. The scores of all the tests were summed to obtain the final score. The minimum and maximum scores of the subjects were 0 and 21, respectively [34, 35]. After performing the tests related to the pre-test (FMS test), the subjects were asked to perform the correct plank position in such a way that the shoulders and elbows formed a 90-degree angle of flexion, the arms were shoulder-width apart, the feet were hip-width apart, the forearms remained in a neutral position, the pelvis was lifted off the floor, and a straight line was formed between the most lateral point of the acromion, the greater trochanter, and the lateral malleolus. The pre-test and post-test measurements were conducted by the same examiner. The subjects were instructed to focus on a specified point in front of them throughout the test to maintain a neutral head position. They were also asked to hold this position for as long as possible, until fatigue prevented them from continuing. They were informed about how to conduct the test beforehand. The researcher gave the same verbal instructions to the athletes during the test. The FMS test was repeated immediately after the plank, and the scores were recorded as post-test results.

2.4. Statistic

The data of subjects' characteristics, such as age, height, weight, and other variables were analyzed using statistical tests in SPSS 24 software. After ensuring the normal distribution of the data by using the Shapiro-Wilk test, the effect of core muscle fatigue on the FMS test was examined using both Wilcoxon and paired t-tests. Cohen's D was used to measure the effect size. An effect size of 0.2 to 0.5 was considered small, an effect size of 0.5 to 0.8 was considered medium, and an effect size of 0.8 or higher was considered large. The significance level was set at $P \leq 0.05$ for all tests.

3. Results

Table 1 shows the demographic characteristics of the subjects. The results of the Shapiro-Wilk test in Table 2 show that the data were not normally distributed in the subscales of the FMS test ($P<0.05$), but the data of the total score of the FMS test were normally distributed ($P<0.05$).

Table 1. The mean and standard deviation of the demographic data of the subjects (N=40)

Variable	M±	SD
Age (years)	23.22	2.75
Weight (kg)	57.40	6.50
Height (cm)	168.52	5.05
History of sporting activities (years)	4.35	0.97
Weekly activities (hours)	6.65	1.29

Table 2. The results of Shapiro-Wilk test for checking the normal distribution of the data in the FMS test

Variable	Timepoint	Statistics	*P*
Deep squat*	Before fatigue	0.700	0.001
	After fatigue	0.517	0.001
Hurdle step*	Before fatigue	0.777	0.001
	After fatigue	0.712	0.001
In-line lunge*	Before fatigue	0.736	0.001
	After fatigue	0.623	0.001
Shoulder mobility	Before fatigue	0.743	0.001
	After fatigue	0.754	0.001
Active straight leg raises	Before fatigue	0.774	0.001
	After fatigue	0.706	0.001
Trunk stability push-up*	Before fatigue	0.634	0.001
	After fatigue	0.736	0.001
Rotary stability*	Before fatigue	0.614	0.001
	After fatigue	0.784	0.001
	Before fatigue	0.931	0.108
	After fatigue	0.047	0.062

* Statistically significant

Table 3. Mean and standard deviation of the FMS test before and after fatigue

Variable	M±SD (before fatigue)	M±SD (after fatigue)	Mean difference
Deep squat	0.55±2.50	0.42±1.77	-0.73
Hurdle step	0.72±2.30	0.54±1.75	-0.55
In-line lunge	0.57±2.35	0.49±1.40	-0.95
Shoulder mobility	0.67±2.42	0.62±2.37	-0.05
Active straight leg raise	0.61±2.02	0.53±1.85	-0.17
Trunk stability push-up	0.53±2.55	0.63±1.55	-1
Rotary stability	0.49±2.62	0.66±1.75	-0.89
Total score of the FMS test	1.47±16.77	1.48±12.45	-0.89

Since the data were not normally distributed in the subscales of the FMS test, the Wilcoxon test was used to compare the whithin-group differences at a significance level of $P \leq 0.05$. Since the data were normally distributed in the total score of the FMS test, the paired t-test was used to compare within-group differences at a significance level of $P \leq 0.05$ (Table 3). All this indicated that fatigue did not significantly affect the scores of the shoulder mobility test and active straight leg raise, but significantly affected the total scores of FMS and five other FMS subscale tests.

4. Discussion

This study was conducted to examine the effect of core muscle fatigue on the scores of the deep squat, hurdle step, in-line lunge, shoulder mobility, active straight leg raises, trunk stability push-up, and rotary stability tests as well as the total score of the FMS test. The results showed that fatigue affected the core muscles in all subscales of the FMS test, except for the scores of the shoulder mobility and active straight leg raise tests. Also, the fatigue of the core muscles affected the total score of the FMS test, and the mean score of test decreased after applying the fatigue protocol. The effect size of core muscle fatigue protocol was 0.752 for deep squat, 0.436 for hurdle step, 0.896 for in-line lunge, 0.862 for trunk stability push-up, and 0.773 for rotary stability, and 1.46 for the total score of the FMS test. The results generally indicated a negative effect of muscle fatigue on the scores of FMS subscales and the total score of the FMS test in female athletes.

Core stabilization exercises can retrain the important function of local trunk muscles, improve proprioception and increase the accuracy of the sensory integration process for stability of the spine in individuals [36]. We found no studies examined the effect of core muscle fatigue on FMS tests in female athletes. Concerning the effect of fatigue on athletes' performance, results of our study were in accordance with Soghari Sheikhi (2016) [37]. Ghorbani et al. (2024) found that core muscle fatigue significantly reduces upper extremity functional test scores and FMS test scores of male athletes [31]. The effect of core muscle fatigue on static and dynamic balance, knee joint proprioception, landing mechanics, endurance, and functional tests' scores has been investigated by previous studies, and the significant reduction of these variables has been confirmed by various tests such as the McGill and Plank tests. Core muscle fatigue reduces the tension or force generated by the core muscles, which in turn diminishes postural control and balance. This fatigue can disrupt neuromuscular processes, leading to both peripheral and central effects on the body. Fatigue disrupts the production of neuromuscular force and negatively affects the body's ability to facilitate contraction while performing functional tasks. Decreased muscle strength due to fatigue increases posture fluctuations and lowers lower limb function in athletes [38].

According to Šiupšinskas et al. (2019), impairment of the functional movement patterns of the FMS test during pre-season screening tests increases the risk of lower limb injuries in female athletes during the training season. They also found that specific systematic functional training, including core stability exercises, may reduce the risk of injury in female basketball players [39]. Sedaghati et al. (2018) argued that there is a significant positive relationship between trunk flexor endurance and balance, as indicated by the FMS scores of female basketball players. Specifically, those with greater muscular endurance tend to achieve higher scores in both the FMS and balance tests [40].

The roles of a strong core are power generation, neuromuscular coordination, precise movement control, proprioception, joint stabilization, muscle co-contraction, and decresed reaction time. These functions can be compromised due to muscle fatigue, which reduces the effectiveness of core muscles in the performance of athletes [41]. This is the logical justification for the reduction of FMS test scores in female athletes in the present study. Finally, this destructive effect on the core muscles and the coordination of these muscles with the lower limb muscles limits functional movements [42, 43]. Muscle fatigue disrupts the contraction of the abdominal and back muscles, leading to lateral displacements of the trunk during the FMS test. This disruption impairs the necessary stability for the movement of the lower limbs across three planes of motion, resulting in a decreased ability to perform functional activities [43]. Impaired core endurance and stability due to fatigue can lead to decreased stimulation of muscle spindles, which weakens proprioception and impairs the function of the lower limbs by affecting balance [44, 45].

The FMS test was developed to assess functional motor capacity [44]. This study found that the FMS test score was 16.77 before applying the fatigue protocol and decreased to 12.45 after core muscle fatigue. This puts athletes at risk of lower limb injuries. The results of this section are in line with the results of the study reported by Ghorbani et al. (2024) on male athletes in which the FMS test scores decreased from 18.3 to 14.92 after fatigue [31]. According to our results, female athletes are more exposed to the effect of core muscle fatigue. This finding that the core muscles are stronger in men than in women [18] indicates that women may be at a higher risk for sports injuries compared to men. Previous studies have found that women tend to have lower core muscle strength compared to men, causing greater instability in their functional activity [18]. This study showed that in-line lunge, trunk stability push-up, and rotary stability were most affected and that there were no differences in the scores of shoulder mobility tests and active straight leg raise before and after muscle fatigue. These findings were consistent with the findings of Ghorbani et al. (2024) who reported that the greatest effect of the fatigue protocol on FMS test scores was in the deep squat, hurdle step, in-line lunge, trunk stability push-up, and rotary stability tests and that the greatest decrease in performance (both in terms of score and quality) was seen in trunk stability push-up and the rotary stability tests [31]. There were no changes in other tests, i.e., active straight leg raise and shoulder mobility. This indicates the relationship between core muscle fatigue protocol and active muscles in these tests. The shoulder mobility and active straight leg raise tests were likely less affected by core muscle fatigue than other tests due to their dependency on flexibility.

Coordination between all core muscles and the lower limbs is essential for achieving optimal scores in functional tests. Fatigue leads to a loss of optimal coordination and negatively impacts performance due to reduced activity in the involved muscles. As a result, movements may be performed incorrectly, neuromuscular coordination patterns may decrease, and the risk of injury might increase due to instability in the vertebral column [46]. It could be argued that core muscle fatigue causes dysfunction along the motor chain probably by negatively affecting neuromuscular coordination, precise movement control, and stability of proximal joints, thereby transferring this destructive effect to distal joints [36, 47]. Also, the negative effects of fatigue cannot be ignored, as the rate of injuries may increase at the end of competitions. The prevalence rate is higher in women due to the structural differences between men and women [37, 48].

By evaluating motor performance through the FMS test in female athletes and considering that the detrimental effect of fatigue is a modifiable factor, this study found that athletic trainers should design exercises to improve core muscle endurance and increase their ability to resist fatigue. This approach can be used as a method to prevent performance reduction due to fatigue during long-term sporting activities. This study has several limitations including lack of a control group, studing only the female athletes and small sample size.

5. Conclusion

The results suggested that muscle fatigue significantly reduced the scores of the deep squat, hurdle step, in-line lunge, trunk stability push-up, and rotary stability tests and that there was no difference in the scores of the shoulder mobility and active straight leg raise tests. Furthermore, core muscle fatigue affected the total score of the FMS test in female athletes, demonstrating a large effect size. Future researchers are recommended to examine the effect of core muscle fatigue on other functional tests and risk of injury in athletes.

Conflict of interest

The authors declared no conflicts of interest.

Authors' contributions

All authors contributed to the original idea, study design.

Ethical considerations

The authors have completely considered ethical issues, including informed consent, plagiarism, data fabrication, misconduct, and/or falsification, double publication and/or redundancy, submission, etc.

Data availability

The dataset generated and analyzed during the current study is available from the corresponding author on reasonable request.

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